

**Effect of Carbohydrate Ingestion During Exercise on  
Performance Measures of Wheelchair Athletes**

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In Partial Fulfillment of the Requirements for the  
Degree of Master of Science in the College of Kinesiology  
University of Saskatchewan  
Saskatoon

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## ABSTRACT

**PURPOSE** The primary purpose of this study was to determine the effect of ingesting an 8% carbohydrate (CHO) beverage during a moderate intensity exercise trial on performance outcomes, fuel utilization and blood glucose levels of wheelchair athletes (spinal cord injury (SCI) or cerebral palsy (CP)). The secondary purpose was to analyze the dietary intake of the eight participants and to determine if they were meeting current sport nutrition guidelines for macronutrients and fluids recommended in the joint position statement developed by the American Dietetic Association (ADA), the American College of Sports Medicine (ACSM) and Dietitians of Canada (DC).

**METHODS** Under random, double blind conditions eight athletes (6 males, 2 females); mean age  $36 \pm 8.5$  y with a SCI ( $n = 7$ ) or CP ( $n = 1$ ) completed two exercise trials on an adapted stationary hand cycle; each trial was 60 minutes in duration at 65 %  $\text{VO}_{2\text{peak}}$  followed immediately by a 30-minute performance trial. During the first 60-minutes the participants were given four 200 ml dosages (15, 30, 45, 60-min) of an 8% CHO beverage or a taste-matched placebo beverage. Blood lactate and glucose levels were sampled during the 60-minute exercise trial (pre, 20, 40, 60-min) and immediately after the 30-minute performance trial (post, 2, 5, 10-min). Heart rate was monitored continuously during the exercise and performance trial. Expired gas samples were also taken for 5-min periods during the exercise trial and then continuously during the performance trial. These values were used to calculate respiratory exchange ratio (RER) and carbohydrate oxidation. Dietary intake was assessed with a three day food record.

**RESULTS** No significant differences were apparent between beverage trials for total

distance (km), average speed ( $\text{km}\cdot\text{hr}^{-1}$ ) or maximum speed achieved ( $\text{km}\cdot\text{hr}^{-1}$ ).

Significant differences were evident for blood glucose values, RER and CHO oxidation between the two beverage trials ( $p < .05$ ). At the end of the 30-minute performance trial blood glucose values were significantly higher in the CHO trial ( $4.8 \pm 1.3 \text{ mmol}\cdot\text{L}^{-1}$  vs.  $4.0 \pm 0.5 \text{ mmol}\cdot\text{L}^{-1}$  for placebo trial;  $p < .05$ ). The CHO beverage resulted in higher CHO oxidation during the last 5 minutes of the performance trial,  $2.1 \pm 1.0 \text{ g}\cdot\text{min}^{-1}$  vs. the placebo beverage  $1.9 \pm 1.0 \text{ g}\cdot\text{min}^{-1}$  ( $p < .05$ ). The CHO beverage trial resulted in significantly higher RER values during the final 5 minutes of the exercise trial and during the final 10 minutes of the performance trial. At the 20-25 minute mark RER values were significantly higher with the CHO beverage trial ( $1.04 \pm 0.10$ ) vs. the placebo trial ( $1.01 \pm 0.11$ ) ( $p < .05$ ). During the final 5 minutes of the performance trial RER values were also significantly higher with the CHO beverage trial ( $1.06 \pm 0.11$ ) vs. the placebo trial ( $1.01 \pm 0.10$ ) ( $p < .05$ ). The results indicated the participants were not meeting the current dietary guidelines for able-bodied athletes and active adults. Only 25% of the participants met the daily caloric requirements for active adults. Carbohydrate recommendations of  $6 \text{ to } 10 \text{ g}\cdot\text{kg}^{-1} \text{ body weight}\cdot\text{d}^{-1}$  were not met by any of the wheelchair athletes. Seven participants were within the acceptable macronutrient range (AMDR) for CHO. For protein intake, 63% of the participants were meeting the protein recommendations active adults and all of them were within the AMDR. Average caloric intake from fat exceeded current recommendations of 20 to 25%; two participants were above the AMDR. The results demonstrate that the 8% CHO beverage consumed during exercise resulted in higher CHO oxidation rates and elevated blood glucose values, but it did not result in a performance gain.

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## **LIST OF ABBREVIATIONS**

AI- Adequate intake

AMDR- acceptable macronutrient distribution range

% BF- percent body fat

BMC- bone mineral content

BMD- bone mineral density

BMI- body mass index

Bpm- beats per minute for heart rate

C- cervical

Ca- Calcium

CHO- carbohydrate

CP- cerebral palsy

DLW- doubly labelled water

DXA- dual-energy x-ray absorptiometry

FFA- free fatty acids

FFM- fat free mass

FS- feeling scale

FP- follicular phase

GI- glycemic index

HG- high glycemic

HR- heart rate

kcal- kilocalories

LBM- lean body mass

LG- low glycemic

LP- luteal phase

RDA- recommended dietary allowance

REE- resting energy expenditure

RPE- rating of perceived exertion

RER- respiratory exchange ratio

SCI- spinal cord injury

T- thoracic

TEF- thermic effect of food

VE- minute ventilation

VCO<sub>2</sub>- carbon dioxide output

VO<sub>2</sub>- oxygen uptake

VO<sub>2max</sub>- maximal oxygen uptake

VO<sub>2peak</sub>- peak oxygen uptake

WHO- world health organization

## CHAPTER 1

### 1.1 INTRODUCTION

The primary objective of this project was to determine the effect of ingesting an 8% carbohydrate (CHO) beverage during a moderate intensity exercise trial followed immediately by a 30-minute performance trial on performance, fuel utilization and blood glucose levels of wheelchair athletes<sup>1</sup> with spinal cord injury or cerebral palsy. The secondary objective was to analyse the dietary intake of the eight participants to determine if they were meeting current able-bodied sport nutrition guidelines for macronutrient and fluid intake as recommended in the American Dietetic Association (ADA), American College of Sports Medicine (ACSM) and Dietitians of Canada (DC) Joint Position Paper *Nutrition and Athletic Performance* (ADA, ACSM, DC, 2000).

During moderate to high intensity exercise, the body becomes dependent on carbohydrate as the primary fuel source for the working muscle tissue. Carbohydrate feeding delays the onset of fatigue and enhances exercise performance by sparing muscle glycogen (Coyle & Coggan, 1984). Carbohydrate feeding may also improve performance by preventing the exercise induced drop in blood glucose (Coyle, 1983). Blood glucose concentration depends on the balance between the rate of glucose entering the blood stream from the liver or digestive tract and the rate of glucose uptake by the active muscle tissue (Coyle & Coggan, 1984). With prolonged exercise, without CHO feeding, blood glucose will drop due to increased demand and decreased supply. A drop in blood glucose leads to an increase in the secretion of the catabolic hormone glucagon, which increases glycogenolysis and gluconeogenesis for the prevention of hypoglycaemia.

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<sup>1</sup> The term wheelchair athlete will be used to describe the participants in the current study. Each participant competes at a national or provincial level within their specific sport.

Fuel utilization has been researched for several decades with able-bodied athletes. Specific CHO ingestion guidelines have been developed to ensure a feeding regime that will provide the body with a supplemental fuel source which can be oxidized in sufficient quantities to delay the onset of fatigue and spare any remaining muscle glycogen stores (Coyle & Coggan, 1984). However, research in the area of fuel metabolism during aerobic exercise in wheelchair athletes is relatively new and presents many unique physiological challenges. Specifically, athletes with a spinal cord injury (SCI) have a loss or impairment of both the sympathetic and parasympathetic responses (Spendiff & Campbell, 2005). These altered responses may impact the action of major organs and hormones that play a direct role in substrate metabolism and cardiovascular response to exercise (Cowel, Squires, & Raven, 1990). Individuals with a SCI have an increased dependency on CHO utilization during exercise, with a decreased ability to utilize lipids as a fuel source even at low exercise intensities (Astorino & Harness, 2009). Encouraging athletes with an SCI to follow the CHO guidelines developed for able-bodied athletes may thus not be appropriate.

To date only three research studies have been published evaluating the impact of CHO ingestion prior to and during exercise on fuel utilisation and performance with wheelchair athletes (Spendiff & Campbell, 2003, 2004, 2005). The studies were conducted with male athletes with an SCI who compete in wheelchair basketball and track events. All three research studies used the same exercise protocol: 1 hour at 65%  $\text{VO}_{2\text{max}}$  followed by a 5-minute rest and then a 20-minute performance test. However, only Spendiff and Campbell (2004) focused on CHO ingestion during the actual exercise bout. They compared the effect of two different drinking schedules; one treatment was 4 doses of 162 ml of a 7.6% CHO beverage, providing 49.25 g of CHO, ingested at the start, at 20, 40 and 60 minutes. The other

treatment was 2 dosages of 324 ml of the 7.6% CHO beverage, providing 49.25 g CHO, ingested at the start and after 60 minutes (Spendiff & Campbell, 2004). Their research design did not include a placebo control trial. When the participants consumed the 7.6% CHO treatment beverage in 4 doses they covered a greater distance during the performance test; however the difference was not statistically significant. The more frequent feeding regime resulted in higher blood glucose values at the end of the exercise trial. Limitations identified from Spendiff and Campbell (2004) included small sample size, lack of a placebo control trial, lack of dietary and physical activity control between the trials, and the overall length of the performance trial may have been too short. They indicated that perhaps a longer performance trial would place greater reliance on exogenous fuel sources (Spendiff & Campbell, 2004).

### **Research Objectives and Hypothesis**

The primary objective of this research study was to assess the impact of the independent variable, CHO beverage consumed, on the total distance covered, average speed and maximal speed during a 30-minute performance trial. In addition we assessed the impact of the CHO beverage on dependent variables; RER, HR, blood lactate, blood glucose, and rating of perceived exertion (RPE) between the exercise and performance trials. It was hypothesized that ingesting the 8% CHO beverage during a moderate intensity exercise trial would maintain blood glucose levels, increase CHO oxidation and improve the performance measures in wheelchair athletes in comparison to a non-caloric placebo control. The secondary research objective was to analyze the dietary intake of the eight participants and to determine if they were within the recommended range of sport nutrition guidelines for able-bodied athletes and

active adults for macronutrient and fluid intake according to the ADA, ACSM, and DC (2000).

## **1.2 LITERATURE REVIEW**

To understand the impact of this research study, it is critical to appreciate what research has been completed with able-bodied athletes in the area of CHO utilization before and during exercise. It is also necessary to identify what has not been conducted with the specific population of interest, wheelchair athletes. During moderate to high intensity exercise, muscle tissue requires a fuel source, primarily CHO (Manore & Thompson, 2000). The CHO supply can come from endogenous sources (gluconeogenesis or glycogenesis) or exogenous sources (foods and fluids). The amount required by the body depends on the intensity of exercise, mode of exercise, fitness level of the participant, duration of exercise, dietary practices of the participant, pre-exercise feeding, and environmental conditions (Manore & Thompson, 2000). Extensive research has been carried out with able-bodied athletes studying CHO and performance during various types of exercise trials (varying durations, intensities, continuous, intermittent) and using different feeding regimes (Coyle et al., 1983; Murray, Seifert, Eddy, Paul, & Halaby, 1989; Below, Mora-Rodriguez, Gonzalez-Alonso, & Coyle, 1995; McConell, Klood, & Hargreaves, 1996). However, research in this area with wheelchair athletes is limited to three studies, two of which have focused on CHO ingestion before exercise and only one that specifically studied the impact of CHO ingestion during exercise.

Due to the level of injury, athletes with SCI have different quantities of active muscle tissue and fat mass. When matched for age and height, males with SCI had 16% less total lean tissue mass versus healthy controls and carried 47% more total fat mass (Jones, Goulding, & Gerrard, 1998). Such a difference in body composition would presumably result in different fuel recommendations

during rest and in particular during exercise when active lean tissue mass would be a critical variable. The following review of literature will focus on the previous research conducted in the area of CHO intake before and during exercise with able-bodied athletes. It will also review the limited research conducted with athletes with an SCI, discussing what is currently known regarding the impact of a SCI on fuel metabolism during exercise and the impact of the SCI on body composition. Three studies that have researched CHO intake before and during exercise with athletes with SCI will also be reviewed, highlighting key findings and research limitations. The ADA, ACSM and DC joint position paper on nutrition and athletic performance will also be presented. Currently no specific recommendations are in place for wheelchair athletes. Therefore the macronutrient and fluid recommendations for able-bodied athletes and active adults will be reviewed.

### **1.2.1 Current Recommendations for Carbohydrate Intake Before and During Exercise**

In 2003 the International Olympic Committee (IOC) Nutrition Working Group developed nutrition guidelines for high performance able-bodied athletes. Based on the current research available, pre-exercise CHO should be consumed based on an athlete's bodyweight and training intensity. Pre-exercise CHO should be consumed in quantities of 1 to 4 g·kg<sup>-1</sup> body weight (Burke, Coyle, & Maughan, 2004). In 1996 the ACSM position statement on exercise and fluid replacement stated that during exercise lasting longer than 1 hour, it is recommended that CHO be ingested at a rate of 30 to 60 g·h<sup>-1</sup> (0.7 g CHO·kg<sup>-1</sup>·h) to maintain oxidation of CHO and to delay the onset of fatigue (Convertino et al., 1996). The IOC guidelines for consumption during exercise are between 20 to 60 g·h<sup>-1</sup> of a CHO source that is readily available to maintain blood glucose. The recommendations for CHO intake during exercise are not based solely on body weight. The CHO dosage is also dependent on athlete tolerance. Ingestion of CHO at concentrations between 4 to 8%



provides enough glucose for maximal uptake and maintains glucose oxidation rates during exercise (Coyle & Montain, 1992). The form of CHO ingested during exercise does not seem to impact the ergogenic effect on exercise performance. Liquid or solid sources have been shown to improve performance to similar degrees (Jeukendrup, 2004).

### **1.2.2 Pre-Exercise Carbohydrate Ingestion Research**

The goals of pre-exercise fuel consumption are to continue to restore liver glycogen stores, especially following an overnight fast, ensure adequate hydration, prevent hunger, avoid gastrointestinal distress, and include foods that the individual feels confident with (Burke & Deakin, 2000).

Early research conducted on CHO focused on avoiding any CHO ingestion before exercise. Coyle et al. (1983) had the participants arrive in a fasted state because it was believed that CHO consumption in the 30 minutes before exercise was detrimental to performance. It had previously been shown that pre-exercise CHO feeding resulted in hyperinsulinemia and an increased usage of muscle glycogen and blood glucose resulting in premature fatigue (Coyle et al., 1983). The feeding regime utilized by Coyle et al. involved a 12-h fast before the start of the exercise trial and the participants were fed either a placebo or glucose polymer after 20 minutes of exercise. The glucose feeding resulted in elevated blood glucose levels during the exercise trial and fatigue was postponed in 7 of the 10 participants. The concern with this recommendation of avoiding CHO pre-exercise was that most endurance athletes would not start a competitive event in a fasted state. The recommendation was thus not thought to be applicable to real life competitions. Therefore subsequent research with able-bodied athletes has studied the effect of specific pre-exercise feeding regimens in addition to varying feeding regimes during exercise.

Results on the effect of pre-exercise CHO feeding on subsequent endurance performance are conflicting. Some have shown that pre-exercise CHO feeding increases endurance performance (el-Sayer, Balmer, & Rattu, 1997) while other studies have shown no effect on performance (Febbraio, Chui, Angus, Arkinstall, & Hawley, 2000). One of the effects with pre-exercise CHO feeding is a change in fuel oxidation, shifting from FFA oxidation to an increase in glucose oxidation (Burke, Claassen, Hawley, & Noakes, 1998). Febbraio et al. (2000) determined the effect of CHO ingestion before, during, or in combination on exercise metabolism and performance. Seven endurance trained men participated in four separate exercise trials. The trials consisted of 120 minutes of steady state (SS) cycling at approximately 70%  $\text{VO}_{2\text{peak}}$  followed immediately by a performance time trial cycle in which the participants were asked to complete a set amount of work as fast as possible (Febbraio et al., 2000). The participants had 1-minute rest between the SS exercise and the performance trial. The trials were performed under double blind conditions and in random order. The participants received either no CHO before or during, placebo 30-minute before and 2 g·kg<sup>-1</sup> body weight CHO in a 6.4% CHO beverage during the SS exercise, 2 g·kg<sup>-1</sup> body weight CHO in a 25.7% CHO beverage 30 minutes before the exercise trial and placebo during the steady state, or 2 g·kg<sup>-1</sup> body weight in a 25.7% CHO beverage 30 minutes before and 2 g·kg<sup>-1</sup> body weight in a 6.4% CHO beverage during the steady state trial. The beverages that were consumed during the SS trial were provided at the onset of exercise and at 15-minute intervals.

During the performance trial the participants did not consume a CHO source but they had access to water when needed. All four SS trials were conducted at the same intensity. The mean  $\text{VO}_2$ , respiratory exchange ratio (RER), heart rate (HR), and rate of perceived exertion (RPE) were not significantly different between the exercise trials. Both CHO before exercise and placebo during and CHO before and CHO beverage during exercise had higher blood glucose values after the ingestion

of the pre-exercise CHO beverage but after 90 minutes of the SS exercise there was no difference in blood glucose levels between any of the four trials. Plasma insulin levels were significantly higher after the pre-exercise CHO intake in the CHO before and CHO beverage during exercise and CHO before plus placebo during exercise trials but there was no difference in values at the onset of the SS exercise trial. The normal hormonal response to exercise is for insulin concentration to be maintained at low levels so that glucose can be utilized as a fuel source and not stored. During the final 30 minutes of the SS exercise plasma glucose concentration was higher in the both groups that were provided with CHO during exercise compared to the trials with the placebo beverage consumed during exercise ( $p<0.05$ ). Fat oxidation was impacted by the amount of CHO that was ingested during the SS exercise. During the final 60 minutes of the SS, FFA and glycerol concentrations were elevated in the placebo trial compared with the other three trials in which CHO was provided either before, during or both ( $p<0.05$ ). In the placebo exercise trial FFA and glycerol levels became elevated due to glycogen depletion. The increased concentration of glycerol is an indirect measure of an increase in lipolysis within the fat cells. Glycerol enters the energy pathway through glycolysis and the free fatty acids enter the citric acid cycle through beta oxidation. Glycerol also provides the carbon skeletons for glucose synthesis (McArdle, Katch, & Katch, 2006). Both trials with CHO provided during the SS exercise resulted in an increase in time trial performance, perhaps because plasma glucose was elevated and better maintained during the final hour of the SS exercise.

The concern with pre-exercise CHO feeding is that it results in metabolic consequences that may harm exercise performance. Much of the debate regarding pre-exercise CHO intake has been focused on its effect on subsequent blood glucose and insulin response. Therefore the natural progression in research would be to examine the effect of glycemic index (GI) of the pre-exercise foods and performance. Glycemic index is a rating of the impact of a CHO load on the blood glucose

response. The index is calculated by measuring the area under the blood glucose curve following the ingestion of 50g CHO of the test food (Siu & Wong, 2004). This value is then compared to the response by 50g CHO of reference food (Siu & Wong, 2004). It is also the rate at which the ingested CHO is made available to intestinal enzymes for hydrolysis and absorption (Coyle, 1991). Foods with a high GI result in a rapid increase in blood glucose levels, and foods with a low GI precipitate a much slower rise in blood glucose. Research has shown that ingestion of low GI foods prior to prolonged exercise may promote the availability of sustained CHO (Siu & Wong, 2004).

Burke et al. (1998) studied the effects of the glycemic index of the pre-exercise meal on metabolism and performance when CHO was ingested according to current guidelines during the exercise trial. Six male cyclists performed 3 exercise trials that consisted of 2 hours of cycling at 70%  $\text{VO}_{2\text{max}}$  followed immediately by a performance trial. The participants were blinded to the treatment. Two hours prior to each exercise the participants were provided with a high glycemic meal (HG), a low glycemic meal (LG), or a control meal with minimal CHO content (1 g CHO, 7 g protein). The CHO content of the glycemic meals were developed to provide  $2 \text{ g} \cdot \text{kg}^{-1}$  body weight. The total caloric contents of the two glycemic index meals were not significantly different. The fluid content of the meal was also controlled, with each meal containing 1,100 ml of fluids. The HG meal had a glycemic index of 87 and the LG meal had a glycemic index of 37.

Thirty minutes after the ingestion of the HG or LG meal blood glucose concentration was significantly greater ( $7.9 \pm 0.6$  and  $6.6 \pm 0.5 \text{ mmol} \cdot \text{l}^{-1}$  respectively) than the blood glucose level following the control meal condition ( $4.4 \pm 0.3 \text{ mmol} \cdot \text{l}^{-1}$ ) (Burke et al., 1998). Blood glucose levels returned to baseline at 60 minutes post meal intake in all three trials. The HG and LG meals consumed pre-exercise also resulted in a suppression of serum FFA concentration ( $<0.1 \text{ mmol} \cdot \text{l}^{-1}$ ) while the FFA levels in the control trial never dropped below the baseline values. Pre-exercise insulin

levels also differed significantly between the three meals. Serum insulin levels were  $74.1 \pm 10.1$   $\text{uU} \cdot \text{ml}^{-1}$  following the HG meal versus  $43.9 \pm 8.9$   $\text{uU} \cdot \text{ml}^{-1}$  after the LG meal. The control meal resulted in fasting serum insulin values less than  $10 \text{ uU} \cdot \text{ml}^{-1}$ .

During the exercise trial the participants were provided with a 10% CHO beverage, immediately prior to, and at 20-minute intervals. When CHO was consumed during exercise at rates of  $1 \text{ g} \cdot \text{min}^{-1}$ , pre-exercise CHO intake had little effect on fuel utilization and endurance performance during a 2.5 h cycle. There was no significant difference in time to complete the performance trial for any of the treatment conditions. Although the participants were blinded to which meal they consumed they all indicated a preference for the LG meal pre-exercise (Burke et al., 1998).

Febbraio and Stewart (1996) investigated the effect of pre-exercise CHO consumption on muscle glycogen utilization and performance during a 2 hr ergometer cycle trial. This study involved three separate exercise and performance trials in which the six male participants were provided with the pre-exercise CHO meal 45 minutes prior to the exercise. The GI of the three meals was controlled. A HG meal, LG meal or placebo control meal was provided pre-exercise during each of the three trials (Febbraio & Stewart, 1996). The participants were endurance trained individuals,  $29 \pm 2$  years of age and  $\text{VO}_{2\text{peak}}$  of  $62.1 \pm 3.6 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$ . Since muscle glycogen content at the start of each exercise and performance trial needed to be consistent a 48 hr food and activity records were used to control for changes in dietary and activity patterns. The exercise trial consisted of 2 hours at 70%  $\text{VO}_{2\text{peak}}$  on a cycle ergometer, and no fuel source was provided during the trial. The participants did have access to 250 ml of water every 15 min. Oxygen uptake, HR and RER values were measured at 15-min intervals during the 2 hr cycle. Carbohydrate oxidation was then calculated from these values. The performance component started 1 min after the completion of the 2 hr cycle. The

participants were instructed to perform as much work (kJ) as possible in 15 minutes. Muscle biopsies were taken immediately before and after the exercise and performance trials.

Respiratory exchange ratio and CHO oxidation values were lower during the placebo meal trial versus the HG and LG meal conditions ( $p < 0.01$ ). The HG meal resulted in higher blood glucose values but only for the sample collected at 15-min into the exercise trial ( $p < 0.01$ ). The HG meal also resulted in significantly lower plasma FFA concentrations compared to the LG meal condition and the placebo meal trial ( $p < 0.05$ ). Muscle glycogen concentration changed significantly from pre-exercise to post but there were no differences noted between the three meal conditions for the post-exercise muscle glycogen content. When assessing the impact of the GI meal on performance, Febbraio and Stewart (1996) stated that there were no performance differences between the three trials. Their main finding was that despite the varying GI of the CHO consumed pre-exercise there was no effect on the rate of muscle glycogen breakdown during exercise (Febbraio & Stewart, 1996).

Education regarding pre-exercise CHO intake should focus on the timing, type, amount, and overall acceptance of the food choices. The point should be stressed that current research does not support the idea that pre-exercise CHO intake decreases endurance performance even when a drop in blood glucose and an increase in FFA utilization occurs at the start of the exercise trial.

### **1.2.3 Research on Carbohydrate intake During Exercise**

More recent research on the impact of CHO on sport performance has focused on the variety of sports and duration of exercise that may benefit from CHO supplementation during exercise. The goal of CHO feeding during exercise is to provide a steady flow of exogenous glucose into the blood with minimal gastrointestinal distress (Coyle, 2004). Coyle and Coggan (1984) stated that CHO ingestion would only benefit exercise performance if the intensity and duration were enough to deplete the

muscle glycogen stores. This suggests that only endurance events lasting 2 to 3 hours in length would benefit. However, Below et al. (1995) demonstrated that CHO ingestion during a 50-minute exercise trial at intensities over 75%  $\text{VO}_{2\text{max}}$  followed immediately by a performance test resulted in improved performance. Four exercise trials took place, one with 1330 ml of a 6% CHO beverage, 1330 ml water, 200 ml of a 40% CHO beverage, or 200 ml water. Both CHO trials were matched for total CHO content ( $79 \pm 4$  g). The performance test involved the completion of a predetermined amount of work (joules) in the fastest time (min). The 6% CHO feeding resulted in significantly higher blood glucose and faster finish time for the performance trial. There were no significant differences noted between the CHO beverages and placebo trial for plasma lactate, heart rate, RER, or oxygen consumption during the exercise trial.

The concentration of CHO consumed during exercise is critical for absorption and utilization. The two primary factors that regulate glucose absorption appear to be concentration of the CHO source and the volume of fluids consumed (Coyle & Montain, 1992). Research with able-bodied athletes has identified an ideal range for CHO concentration of 4 to 8% during moderate to high intensity exercise (Coyle & Montain, 1992). Ingestion of CHO beverages at this concentration provides enough glucose for maximal uptake and maintains oxidation rates during exercise (Coyle & Montain, 1992).

Exercise represents a physiological stress placed on the body which then requires major cardiovascular and metabolic adjustments to maintain homeostasis (Meeusen, Watson, Hasegawa, Roelandst, & Piacentini, 2007). Exercise causes an increase in cortisol, glucagon and sympathetic nervous system hormones (epinephrine and norepinephrine) in order to increase fuel availability (Coyle, 1983). In order for the body to adjust to these changes, the central nervous system (CNS) needs to be provided with a sufficient glucose and oxygen supply (Meeusen et al., 2007). The

maintenance of blood glucose during exercise in order to meet the needs of the CNS is therefore a critical component in preventing the onset of fatigue. Nybo (2003) investigated how glucose supplementation during prolonged exercise would affect neuromuscular activation, looking at a sustained maximal voluntary muscle contraction measured by a strain gauge dynamometer immediately after a 3-hour cycle trial. The participants were provided with either a 6% glucose beverage to maintain blood glucose levels or a placebo drink leading to the development of hypoglycaemia. The total amount of CHO provided in the glucose trial was  $200 \pm 10$  g and the total volume of fluid consumed during both trials was  $3.3 \pm 0.2$  litres. The placebo beverage led to a significant increase in RPE ( $16 \pm 1$  vs.  $13 \pm 1$  in the glucose trial) during the last hour of the cycle trial. The placebo trial, which led to the development of hypoglycaemia, was also associated with an impaired neuromuscular performance during the sustained contraction (Nybo, 2003). The initial onset of force was similar between the placebo and glucose trials but the hypoglycaemia that ensued with continued exercise impaired the ability to sustain high neural drive over time. Nybo suggested that “the mechanism underlying the hypoglycaemia-induced central fatigue could be a direct effect of reduced substrate delivery to the brain”. Carbohydrate supplementation during exercise was able to prevent the onset of hypoglycaemia and maintain activation drive from the CNS, delaying central and peripheral fatigue (Nybo, 2003).

#### **1.2.3.1 Carbohydrate Feeding Late in Exercise**

Another feeding strategy that has been researched with the able-bodied athlete population is the ingestion of CHO late in exercise once muscle glycogen and blood glucose levels are starting to diminish (McConell, Klood, & Hargreaves, 1996). The researchers' aim was to see if CHO consumed late in exercise would be of greater benefit to exercise performance versus intermittent CHO feeding



from the start of the trial. The total amount of CHO consumed during the 2-hour cycle was the same in the 7% CHO trial and the 21% CHO trial. The total dosage was 157.5 g CHO. It was hypothesized that ingestion of a large amount of CHO late in exercise would improve 15-minute performance to the same extent or greater than CHO ingestion throughout the exercise trial (McConell et al., 1996). The exercise trial was a 2-hour bicycle ride at 70%  $\text{VO}_{2\text{peak}}$  followed immediately by a 15-minute performance ride. The results did not support their research hypothesis. When the 7% CHO beverage was consumed every 15 minutes during the 2-hour exercise trial the participant's ability in the performance ride was significantly increased as indicated by increased work output in comparison to the placebo trial ( $p < 0.05$ ). Providing the 7% CHO beverage during the 2-hour cycle improved the performance of seven of the eight participants compared to feeding 21% CHO late in exercise. It was concluded that the negative impact of not consuming CHO for the first 90 minutes of the exercise trial carried over to the performance in the 15 minute trial.

#### **1.2.4 Composition of Carbohydrate Consumed During Exercise**

Carbohydrate consumption during exercise has been shown to be limited due to the rate of absorption. Jeukendrup (2004) concluded that absorption of a single CHO source during exercise would plateau at approximately  $1.0 \text{ g} \cdot \text{min}^{-1}$ . The cause of this plateau is thought to be the limitation of the transportation of glucose across the cell membrane. Saturation of glucose transport proteins, GLUT-2 and sodium dependent glucose transporter-1 (SGLT-1) may occur, limiting the CHO oxidation rate during exercise. In an effort to address this issue, several studies have focused on the impact of consuming multiple simple CHO sources to see if oxidation could be increased, thereby increasing endurance performance. Providing a combination of CHO sources increases exogenous CHO oxidation rates during exercise because glucose and fructose are absorbed by different intestinal

transport mechanisms. Glucose uses SGLT1 and fructose uses GLUT-5 transporters. With different mechanisms of transport there would likely be less competition for absorption leading to enhanced transport of both substrates (Jeukendrup, 2004).

Jentjens & Jeukendrup (2005) investigated whether a mixture of glucose (GLUC) and fructose (FRUC) when ingested at a high rate ( $2.4 \text{ g} \cdot \text{min}^{-1}$ ) would lead to even higher exogenous CHO oxidation rates ( $>1.3 \text{ g} \cdot \text{min}^{-1}$ ). The participants were eight trained male endurance athletes, with a mean age of 26 years, and a mean  $\text{VO}_{2\text{max}}$  of  $68 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ . Each participant performed three exercise trials which consisted of 150 minutes at 50% maximal power output ( $W_{\text{max}}$ ) while ingesting either a 9.23% GLUC beverage, an 18.46% GLUC and FRUC beverage (9.23% of each), or water. The treatment beverages were provided in a 600 ml bolus during the first 3 minutes and 150 ml bolus at 15 minutes intervals during the exercise trial. The average amount of glucose consumed during the GLUC trial was  $1.2 \text{ g} \cdot \text{min}^{-1}$  and for the GLUC and FRUC trial the average dosage was  $2.4 \text{ g} \cdot \text{min}^{-1}$ .

The rate of CHO oxidation was significantly higher in the GLUC trial versus the control trial. During the 60<sup>th</sup> to 150<sup>th</sup> minute of the exercise trial CHO oxidation was significantly higher in the GLUC and FRUC trial compared to the control trial. Fat oxidation was significantly lower during the two CHO trials; fat represented 61% of the total energy in the water trial and only 34% in the GLUC and FRUC trial. The rate of endogenous CHO oxidation was significantly lower in the two CHO trials compared with the water trial:  $1.6 \text{ g} \cdot \text{min}^{-1}$  during the water trial and  $1.1 \text{ g} \cdot \text{min}^{-1}$  during the GLUC and FRUC trial. No difference was found between the two CHO trials regarding endogenous CHO oxidation. Maximal glucose oxidation rates were reached when glucose was ingested at  $1.2 \text{ g} \cdot \text{min}^{-1}$ . Findings from this study support the sparing effect of CHO ingestion during exercise on the muscle and liver glycogen stores. Combined ingestion of large amounts of glucose and fructose

during 150 minutes of cycling exercise resulted in approximately 50% higher CHO oxidation rates compared with glucose alone. Peak CHO oxidation values for glucose plus fructose was  $1.75 \text{ g} \cdot \text{min}^{-1}$ .

In order to achieve high CHO oxidation rates during exercise, endurance athletes should be advised to consume a mixture of CHO sources at dosages that provide  $1.2 \text{ g} \cdot \text{min}^{-1}$  of each source (Jentjens & Jeukendrup, 2005). Since the total amount of fuel consumed would be quite large, this recommendation would only benefit performance if an athlete could physically tolerate the fuel load. This study claims to have demonstrated that during the GLUC and FRUC trial, the oxidation rate of  $1.75 \text{ g} \cdot \text{min}^{-1}$  could have been the highest oxidation rate that is physiologically possible when multiple transportable CHO sources are ingested orally (Jentjens & Jeukendrup, 2005).

It is of note that consuming large amounts of only fructose during endurance exercise is not recommended because it has a slower absorption rate compared to glucose or sucrose. Therefore it has the potential to lead to gastrointestinal upset (Jentjens & Jeukendrup, 2005). Jentjens & Jeukendrup did not find any differences in gastrointestinal discomfort between all three trials. The most common complaints were an urge to urinate and a feeling of being bloated.

In a subsequent study Jentjens et al. (2006) studied whether a glucose and fructose beverage would result in greater CHO oxidation and higher fluid availability during exercise in the heat versus an isocaloric glucose beverage. A previous study had shown that a combination of CHO sources (glucose and fructose) resulted in high exogenous oxidation rates (Jentjens & Jeukendrup, 2005), but the same response was not shown with exercise trials conducted in the heat. The exercise trial was 120 minutes at 50% maximal power output at an ambient temperature of 32 degrees Celsius. The study was comprised of 3 trials. Three treatment beverages were provided in random order with  $1.5 \text{ g} \cdot \text{min}^{-1}$  glucose,  $1.0 \text{ g}$  glucose plus  $0.5 \text{ g} \cdot \text{min}^{-1}$  fructose, or plain water (Jentjens et al., 2006). Dosages for the three treatment beverages were a bolus amount of 600 ml consumed during the first three

minutes of the exercise trial and 200 ml every 15 minutes, resulting in a total beverage intake of approximately 2 litres. The total CHO intake was 180 g of either glucose only or 120 g of glucose and 60 g of fructose. The CHO concentration of the beverages was 9%.

Exogenous CHO oxidation rates during the last hour of exercise were 36% higher in the glucose plus fructose group compared to the glucose only trial ( $p < 0.05$ ). Peak oxidation rates during the exercise trials were  $1.1 \text{ g} \cdot \text{min}^{-1}$  for the glucose plus fructose trial and  $0.8 \text{ g} \cdot \text{min}^{-1}$  for the glucose trial (Jentjens et al., 2006). Endogenous CHO oxidation was significantly lower ( $p < 0.05$ ) in the glucose plus fructose trial compared to the water trial. During the last part of the exercise trial (90 to 120 min) the rate was  $1.0 \text{ g} \cdot \text{min}^{-1}$  for glucose plus fructose trial versus  $1.5 \text{ g} \cdot \text{min}^{-1}$  for the water trial. Muscle glycogen oxidation was not significantly different between the glucose and the water trial. The two CHO trials significantly reduced fat oxidation rates compared to the water trial. Fat oxidation represented  $61 \pm 4$ ,  $48 \pm 3$  and  $45 \pm 1$  % of total energy expenditure in the water, glucose, and glucose plus fructose trials respectively. Ingestion of glucose and fructose in combination resulted in high CHO oxidation rates ( $> 1.0 \text{ g} \cdot \text{min}^{-1}$ ) and reduced endogenous CHO oxidation by approximately 26% compared with the water trial. Since exercising in the heat has been shown to increase muscle glycogen utilization (Jentjens et al., 2006), using a combination of CHO sources during exercise may delay the onset of fatigue by sparing endogenous CHO sources.

### **1.2.5 Impact of Gender on Fuel use During Exercise**

Most studies that have assessed fuel utilization during exercise with the athletic population have used a sample of only male athletes (Brisswalter et al., 2000; Katsumi & Kando, 1998; Dumke et al., 2007; Below et al., 1995). Women have lower RER values during exercise in comparison to men, indicating a greater reliance on fat oxidation (Devries, Hamadeh, Phillips, & Tarnopolsky, 2006;

Braun, Gerson, Hagobian, Grow, & Chipkin, 2005). The reduced oxidation of CHO during exercise could be due to a decreased utilization of muscle glycogen, lower utilization of blood glucose, or both (Horton, Grunwald, Lavelly, & Donahoo, 2006). The variation in estrogen concentration between genders play an important role in these noted differences (Devries et al., 2006). The current study included female wheelchair athletes, therefore menstrual cycle hormonal fluctuations will be discussed. McLay, Thomson, Williams and Rehrer (2007) stated that it is important to control for menstrual cycle phase in all exercise metabolism studies involving female participants, due to the potential influence that fluctuations in endogenous sex hormones have on muscle glycogen concentration. Hackney (1999) found that muscle glycogen utilization was lower during the luteal phase when oestrogen was the highest and that a significant negative relationship existed between oestrogen level and glycogen utilization. Respiratory exchange ratio was significantly lower in the luteal phase versus the follicular phase, suggesting enhanced lipid utilization during exercise (Hackney, 1999). Bailey, Zacher and Mittleman (2000) studied the impact of a CHO beverage consumed during exercise to see if providing a fuel source during exercise would negate the impact of the menstrual cycle on fuel utilization. Their research design involved four exercise trials, two during the luteal phase and two during the follicular phase. During both phases the nine female participants were provided with either a 6 % CHO beverage or placebo. The beverages were provided every 30 minutes and the participants were told to cycle to exhaustion. Their results indicated that the time to exhaustion was increased with the CHO beverage but there was no difference between the luteal and follicular phase. There was also no difference between phases for FFA, plasma glucose or insulin levels.

### **1.2.6 Impact of Carbohydrate Ingestion on Rating of Perceived Exertion**

Most research focuses on the impact of feeding on quantitative measures such as blood glucose, plasma insulin, lactate, etc., because they provide values that are easier to compare across different study designs. It is equally important however to also understand the qualitative impact of these changes. The qualitative questions are more challenging to interpret, but their importance may provide additional insight into the performance benefit of CHO feeding.

Backhouse, Bishop, Biddle, & Williams (2005) examined the influence of regular CHO beverage consumption on affect (pleasure-displeasure) and rating of perceived exertion (RPE) during a 2 hour cycle at approximately 70%  $\text{VO}_{2\text{max}}$ . The research protocol involved nine endurance male athletes, the design was randomized and under double-blinded conditions. The exercise trials provided the athletes with either a placebo immediately before the exercise trial and at 15-minute intervals during exercise or a 6.4% CHO beverage ( $5 \text{ ml} \cdot \text{kg}^{-1}$  bodyweight) before and  $2 \text{ ml} \cdot \text{kg}^{-1}$  bodyweight at 15-minute intervals during exercise. The methodology that was used involved the feeling scale (FS) to measure the affective dimension of pleasure to displeasure (Backhouse et al., 2005). It is an eleven point scale from  $-5$  meaning very bad to  $+5$  meaning very good. The FS was administered pre-exercise, at 15-minute intervals, and in the post exercise phase. The RPE scale was administered every 15 minutes during the exercise trial to monitor the perceived exertion of the participants. Heart rate was also monitored. Dietary intake was recorded for 2 days prior to each exercise trial and there were no significant differences between energy intake and composition between the trials. Heart rate and percent  $\text{VO}_{2\text{max}}$  did not differ between trials indicating that exercise intensity measured using quantitative scales were similar in both trials. Plasma glucose was significantly higher immediately post exercise in the CHO trial compared with the placebo trial, with values of  $6.1 \pm 0.3 \text{ mmol} \cdot \text{l}^{-1}$  and  $5.4 \pm 0.3 \text{ mmol} \cdot \text{l}^{-1}$ , respectively. The overall pleasure ratings were

higher during the CHO trial and recovery period compared with the placebo trial. For the placebo trial the FS indicated that the pleasure ratings were becoming less positive as the exercise trial continued. At 75 minutes the RPE was significantly lower in the CHO trial compared with the placebo trial ( $p<0.05$ ).

Utter et al. (2007) studied the impact of CHO feeding during intermittent exercise on RPE with 12 male cyclists. The exercise trial included 2 hours at 73%  $\text{VO}_{2\text{peak}}$  with 3-minute rest intervals every 10 minutes. The participants were provided with a 6% CHO beverage or a placebo beverage 15 to 30 minutes pre-exercise and at 15-minute intervals during the trial. During the last minute of each 10-minute bout of exercise the participants rated their overall body RPE. The RPE patterns were significantly lower during the CHO versus placebo trials. A critical limitation to this study was the pre-exercise feeding protocol. The participants were instructed to arrive at the testing site following a 5 hour fast. During the placebo trial the participants would then not receive any form of energy for another 2 hours.

### **1.2.7 Current Dietary Guidelines for Able-Bodied Athletes**

The current recommendations for able-bodied athletes and active adults are from a joint position paper *Nutrition and Athletic Performance* (ADA, ACSM, DC, 2000, 2009). The joint position paper was developed by the ADA, ACSM and DC. Currently there are no specific dietary recommendations for wheelchair athletes. Therefore, able-bodied guidelines will be used for comparison. The position paper is focused on recommendations for adult athletes and does not focus on a specific type of sport or competitive event.

The first priority for all athletes is to achieve an energy balance. Energy balance is vital for maintaining muscle tissue, proper immune function, reproductive function for female athletes, and

optimal sport performance (ACSM, ADA, DC, 2000). The energy requirements of the human body are divided into three components; resting energy expenditure (REE), the thermic effect of food (TEF) and the energy expended with daily life and physical activity. Collectively, the components determine each individual's total daily energy requirements. Active adults are advised to consume an energy intake of 1.5 to 1.7 times their REE or to consume between 37 to 41 kcal·kg<sup>-1</sup>·d (National Research Council (NRC), 1989). Numerous equations exist for calculating REE for adults. Currently there are not any specific equations for wheelchair athletes. Note that the World Health Organization (WHO) energy equations for resting energy expenditure are designed for able-bodied individuals, and thus, they may not be suitable for individuals with a chronic disease or disability (Abel, Platen, Rojas Vegas, Schneider, & Struder, 2008).

Abel et al. (2003) measured resting energy requirements for 27 athletes with varying levels of physical ability (SCI, spina bifida, amputations, post-polio syndrome). They found basal metabolic rate to be  $65.4 \pm 14.1$  kcal·h<sup>-1</sup> for the hand bike athletes and  $60.3 \pm 9.1$  kcal·h<sup>-1</sup> for the wheelchair racing athletes. These values would result in resting daily requirements of 1,488 to 1,560 kcal·d<sup>-1</sup> plus additional energy needs for physical activity. Taking their findings and applying them to all groups of wheelchair athletes would not be appropriate. Since there are no specific energy recommendation for wheelchair athletes able-bodied guidelines for active adults, 37 to 41 kcal·kg<sup>-1</sup>·d<sup>-1</sup>, will be used for comparison in this study. This limitation in available evidence suggests that we can only assume that the current dietary recommendations for able-bodied athletes can be applied to wheelchair athletes (Broad, 2006, p. 747).

Daily CHO intake is crucial for optimal sport performance. In previous sections, we have discussed in detail the optimal timing and type of CHO intake before and during exercise. The recommendation for total CHO is 6 to 10 g·kg<sup>-1</sup>body weight·d<sup>-1</sup> (ACSM, ADA, DC, 2000). The CHO



recommendation represents the CHO dosage necessary to maintain blood glucose levels and restore muscle glycogen levels on a daily basis. Carbohydrate intake is crucial for athletes training in endurance and strength events (Burke, Kiens, & Ivy, 2004). The availability of CHO as a fuel source for exercising muscles and the central nervous system becomes a limiting factor in sport performance (Burke et al., 2004). Daily CHO intake can therefore limit performance in both endurance events over 90 minutes and intermittent high-intensity exercises (Burke et al., 2004). The current CHO guidelines are based on research which found that the threshold for glycogen storage was achieved with an intake of 7 to 10 g·kg<sup>-1</sup> body weight·d<sup>-1</sup> (Costill et al., 1981).

Daily protein recommendations for able-bodied athletes are higher than the current recommended dietary allowance (RDA) of 0.8 g·kg<sup>-1</sup>·d<sup>-1</sup>. Recommended dietary allowances are defined as “the average daily dietary nutrient intake level sufficient to meet the nutrient requirements of nearly all (97 to 98%) healthy individuals in a particular life stage and gender group” (Institute of Medicine (IOM), 2004). The ACSM, ADA, DC (2000) protein recommendation for strength-trained athletes is to consume between 1.6 to 1.7 g·kg<sup>-1</sup> body weight·d<sup>-1</sup>. The recommendation for endurance trained athletes is 1.2 to 1.4 g·kg<sup>-1</sup> body weight·d<sup>-1</sup>. These recommendations for additional protein intake above the RDA are to account for a small percentage of protein being used as a fuel source during exercise and to allow for complete muscle recovery post-exercise (Lemon, 1998). Fat intake is an important component to an athlete’s diet; however, there is no performance advantage to consuming a very fat restricted diet (ACSM, ADA, DC, 2000). The current recommendation is based on a percentage of total energy intake. Fat should provide between 20 to 25% of total caloric intake. Including healthy sources of fat on a daily basis will ensure that athletes meet their requirements for fat soluble vitamins (A, D, E and K) and essential fatty acids.

The recommendations for total fluid intake are gender specific. The adequate intake (AI) for females is 2,700 ml and for males is 3,700 ml. An AI value is “the recommended average daily intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group of apparently healthy people that are assumed to be adequate when and RDA cannot be determined” (IOM, 2004). The AI for fluids includes total water (beverages, drinking water, and foods). Approximately 80% of total water intake comes from fluids but 20% is accounted for by foods consumed (IOM, 2004).

#### **1.2.7.1 Dietary Assessment Tools**

Dietary assessment can be conducted in numerous ways (e.g. 24 hour food recall, food frequency questionnaire, weighed food record), each method having strengths and weaknesses. For the 24 hour food recall and the food frequency questionnaire, both are completed by memory therefore the assessment tool not have impacted intake. Since the accuracy of the tools is depended on memory, errors may occur (Block & Hartman, 1989). The chosen method for the current study was a 3-day food record. The primary purpose of the 3-day food record was to control for dietary intake leading into both exercise and performance trials. The secondary purpose of the 3-day food record was to assess the participant’s dietary intake. One of the main advantages with this method is that it is not reported by recall (Hyman et al., 1982). The researcher can also gain detailed information on food intake patterns, food preparation and quality of choices (Hammonds, 2000). Some of the disadvantages with 3-day food records are: issues with underreporting, that it requires participants to measure accurately and judge portion sizes, and the impact of the measurement effect (Hammonds, 2000). Underreporting is widespread among athletes and its magnitude should be addressed when interpreting the results (Magkos & Yannakoulia, 2003). Food records have been compared against the

gold standard for energy expenditure in human participants, doubly labelled water (DLW). Edwards, Linderman, Mikesky, and Stager (1993) found that for endurance female athletes the percent of energy underreported from a 7-day food record compared to DLW was  $-29.8 \pm 17.9\%$ . Ebine, Rafamantanantsoa, and Nayuki (2002) revealed that underreporting was also a concern with male athletes. The percent of energy recorded in the 7-day food record compared to DLW was  $-12.4 \pm 9.1\%$ . A weighed 7-day food record would be a more accurate measure but it is not portable and athletes frequently eat away from home due to their training schedule. Another possible limitation of the food record is the measurement effect. The measurement effect is the tendency for participants to change their eating habits while keeping the food records (Hyman et al., 1982). As a method to control for dietary intake between the exercise and performance trials, a 3-day food record will enhance the internal validity of the research study. It also ensures greater dietary control than the previous research conducted in this area with wheelchair athletes (Spendiff and Campbell, 2005, 2004, 2003).

#### **1.2.8 Current Research with Wheelchair Athletes**

Wheelchair athletes with a SCI experience a loss of motor function, sensation and control of autonomic function at and below the level of injury (Spendiff & Campbell, 2004). They also experience unique changes to their cardiorespiratory, metabolic and thermoregulatory systems that reduce their overall physiological capacity (Bhambhani, 2002). Paraplegic athletes exhibit cardiac limitations at peak exercise contributing to lower  $VO_{2\text{peak}}$  (Vinet et al., 1997). An explanation for the reduction in  $VO_{2\text{peak}}$  may be a reduction in active muscle tissue (Vinet et al., 1997). In addition, cardiac limitations, such as a lower stroke volume, are explained by a loss of central sympathetic vasomotor outflow and a loss of muscle pump action below the level of the injury (Vinet et al., 1997).

A decrease in muscle blood flow would have a direct impact on nutrient delivery to the active muscle tissue during exercise.

When physiological responses are evaluated across a range of spinal cord injury levels in wheelchair athletes, important considerations need to be taken into account. Heart rate, blood lactate levels,  $\text{VO}_{2\text{max}}$ , and cardiac output are inversely related to the level of lesion (Bhambhani, 2002). Training may negate some of these physiological differences. Campbell, Williams and Lakomy (2004) reported that endurance-trained athletes with SCI were able to maintain velocities equivalent to the same relative exercise intensity ( $75\% \text{VO}_{2\text{peak}}$ ) for prolonged periods regardless of injury level. The target population for this research project was trained wheelchair athletes with different spinal cord injury levels and physical impairments.

Campbell et al. (2004) examined the physiological and metabolic responses of athletes with SCI in different racing classes, dependent on level of injury, for 90 minutes at  $75\% \text{VO}_{2\text{peak}}$ . Twenty athletes with a variety of SCI levels participated in the research study. The athletes were grouped by injury level according to the Paralympic Racing Classification system (Campbell et al., 2004). Eight athletes were in the T3 racing category, indicating athletes with paraplegia with a lesion level between thoracic (T) T1 to T7. Nine athletes were in the T4 racing class (paraplegia with lesion levels below T7). Their results indicated that few differences were found between the physiological and metabolic response of the two racing classes. However differences were found with respect to heart rate response during the exercise regime. During the 90-minute test a gradual increase in heart rate similar to that experienced by able-bodied athletes was only apparent in the T4 athletes. The athletes in the T3 class experienced a heart rate plateau after an initial increase at the onset of the exercise regime. The T3 athletes have less recruitable muscle mass; therefore, stroke volume and heart rate may remain stable because there would be less competition between the muscle tissue and skin for the

blood volume as the athlete's body temperature increases (Campbell et al., 2004). Due to the higher level of SCI in the T3 group, HR may have been limited due to disruptions to the sympathetic nervous system (Bhambhani, 2002).

For both groups of athletes the RER values decreased significantly as the exercise test progressed ( $p<0.05$ ). Respiratory exchange ratio values of 0.91 for the T3 athletes and 0.92 for the T4 athletes at the start of the exercise dropped to 0.82 for the T3 athletes and 0.80 for the T4 athletes at the completion of the 90-minute exercise. The decrease in RER as the exercise regime progressed indicates a switch to lipid metabolism. The results of this study also indicated that protein metabolism contributed to the total energy expenditure of the exercise regime. By the end of the 90-minute test, plasma ammonia and urea concentrations had significantly increased from resting values for the paraplegic athletes ( $p<0.05$ ). These results are consistent with exercise testing in the able-bodied population.

#### **1.2.9 Research Conducted on Fuel Utilization with Wheelchair Athletes**

One of the challenges in working with wheelchair athletes is that not much is known regarding their fuel requirements during exercise. Most of the research conducted in the area of rehabilitation, not high performance sport (Bhambhani, 2002). Limited research with this population has shown that the primary substrate utilized during submaximal wheelchair exercise is glycogen, as shown by depletion of glycogen in the deltoid muscle (Bhambhani, 2002). Knetchle, Muller, Willmann, Eser, and Knecht (2004) assessed the rate of fat oxidation at three different exercise intensities in trained athletes with SCI. The three exercise trials were 20 minutes in length at intensities of 55, 65 and 75%  $VO_{2peak}$ , and the participants had 15 minutes of rest between each trial. Fat oxidation in wheelchair cycling, in contrast to cycling and running with able-bodied athletes, did not differ between the three

exercise intensities (Knetchle et al., 2004). The study did show that CHO oxidation increased from  $1.1 \pm 0.4 \text{ g} \cdot \text{min}^{-1}$  at 55%  $\text{VO}_{2\text{peak}}$  to  $1.7 \pm 0.5 \text{ g} \cdot \text{min}^{-1}$  at 75%  $\text{VO}_{2\text{peak}}$  ( $p < 0.05$ ).

Astorino and Harness (2009) also examined the impact of an SCI on substrate metabolism at rest and during exercise. Nine men and women with an SCI participated in the study which involved two 30-min submaximal exercise trials. RER values increased significantly from  $0.85 \pm 0.07$  at rest to  $0.95 \pm 0.01$  during exercise ( $p < 0.05$ ). Carbohydrate oxidation increased during the exercise trials, peaking at  $2.6 \pm 0.3 \text{ g} \cdot \text{min}^{-1}$  (Astorino & Harness, 2009). Their findings further demonstrated that individuals with an SCI are dependent on CHO as the dominant fuel source during low to moderate intensity exercise. These results are important for all wheelchair athletes, especially those with a high levels of injury. Their ability to store adequate muscle glycogen for their competitive event or training session would be further compromised due to a reduction in active muscle tissue. These findings support the notion that additional exogenous CHO may be needed to maintain endurance training performance. Providing athletes with the top end of able-bodied athlete's CHO recommendations during exercise may allow the athletes to train for longer time periods and enhance their endurance capacity.

To date only three studies have been published examining the CHO needs during exercise of athletes with SCI (Spendiff & Campbell, 2003, 2004, 2005). Their studies were conducted with male athletes that compete in wheelchair basketball and track events. All three research studies used the same exercise protocol. One hour at 65%  $\text{VO}_{2\text{max}}$  followed by a 20-minute performance test. Only Spendiff and Campbell (2004) focused on CHO intake during exercise. They compared the effect of two different drinking schedules. One treatment was 4 doses of 162 ml of a 7.6% CHO beverage, providing 49.25 g of CHO, ingested at the start and at 20, 40 and 60-minute marks. The other treatment was 2 dosages of 324 ml of the 7.6% CHO beverage, providing 49.25 g CHO, ingested at

the start and after 60 minutes. When the seven participants consumed the 7.6% CHO treatment beverage in 4 doses they covered a greater distance during the performance test; however the difference was not statistically significant. There was a significant difference between the feeding regimes with regard to blood glucose fluctuations; specifically the 4 x 162 ml protocol resulted in more steady blood glucose levels. The blood glucose values for the 4 x 162 ml feeding regime ranged from  $3.6 \pm 0.6 \text{ mmol}\cdot\text{l}^{-1}$  at rest up to  $4.9 \pm 1.0 \text{ mmol}\cdot\text{l}^{-1}$  at the 40-min mark. Respiratory exchange ratio of  $0.91 \pm 0.05$  throughout the whole exercise and performance trial may suggest a steady rate of CHO oxidation during the 4 x 162 ml protocol. The RER values for the 2 x 324 ml protocol decreased over the course of the 60-minute trial, indicating a switch in fuel sources and increase utilization of fatty acids. The 2 x 324 ml feeding regime resulted in a greater increase in FFA concentrations during the exercise trial. This indicated that the CHO feeding was not enough to maintain the plasma glucose concentrations and RER values.

Providing a CHO at frequent intervals during exercise at moderate intensity suppresses endogenous glucose production in able-bodied athletes, allowing for a decrease in the rate of hepatic gluconeogenesis (Jeukendrup et al., 1999). Focusing on blood glucose is critical because if it can be maintained along with CHO oxidation, as shown with higher RER values, then this might improve exercise performance in sprint finish events (Spendiff & Campbell, 2004). This would have a direct impact on real world athletic performance.

Spendiff and Campbell (2003) focused on pre-exercise CHO feeding in athletes with SCI. Eight participants were provided with either a beverage containing 48 g of CHO or a placebo beverage 20 minutes prior to the exercise protocol. The exercise protocol was conducted on an arm crank ergometer. Participants covered more distance in the 20-minute performance trial when the CHO source was consumed pre-exercise,  $10.83 \pm 0.74 \text{ km}$  versus  $10.20 \pm 1.01 \text{ km}$  with the placebo

beverage ( $p < 0.05$ ). Building on these findings, Spendiff and Campbell (2005) investigated the performance impact of varying CHO concentration with eight athletes with a SCI. They chose two treatment beverages: 4% CHO or 11% CHO consumed in one dose 20 minutes before the exercise trial. The participants received either 24 g (4% CHO) or 72 g (11% CHO) of dextrose in a 600 ml solution, and no beverage was provided during the exercise trial or performance ride. The exercise and performance trial was conducted on a wheelchair roller system and consisted of 60 minutes at 65%  $\text{VO}_{2\text{peak}}$  followed by a 20-minute performance test.

The lower CHO feeding regime resulted in a greater increase in FFA at the end of the 60-minute exercise trial ( $p < 0.05$ ). The results indicated no difference in distance covered or mean power output during the 20-minute performance ride between the two CHO beverages. There was no significant difference in the  $\text{VO}_2$ , minute ventilation, RER, heart rate, blood lactate, and blood glucose concentrations between the high and low CHO trials. Spendiff and Campbell noted that due to the small sample size a significant difference was not found but there was a trend towards higher RER and blood glucose concentrations in the performance trial following the high CHO beverage compared to the low CHO dosage. The trend towards an increased rate of CHO oxidation, indicated by the elevated RER values, in the high CHO trial may have caused a slight shift in substrate utilization from FFA to glucose. The findings from this study suggest that low lesion paraplegic athletes who possess a smaller amount of active muscle mass respond in a similar way to pre-exercise CHO ingestion as able-bodied athletes (Spendiff & Campbell, 2005).

Limitations identified from Spendiff and Campbell (2005) included small sample size, lack of dietary and physical activity control between the trials, and the duration of the exercise trial. Spendiff and Campbell also suggested that future research should increase the duration of the performance trial to increase the reliance on exogenous CHO sources.



Even though no performance difference was found, the benefit of a high CHO dosage may be important to investigate further since wheelchair athletes have a lower amount of active muscle tissue. Therefore their ability to store glycogen in preparation for competitive events may be compromised (Bhambhani, 2002). If muscle glycogen stores are minimal at the onset of exercise, exogenous CHO may become a more crucial energy source for prolonged events. Building upon the knowledge gained from these three research studies and minimizing many of the limitations noted (Spendiff & Campbell, 2003, 2004, & 2005); the current study implemented a frequent CHO feeding regime during a moderate intensity exercise trial in an attempt to improve performance during prolonged exercise.

## **CHAPTER 2**

### **2. METHODS**

#### **2.1 Participants**

This research project included eight participants with varying levels of ability (SCI = 7, CP = 1) from national and developmental level wheelchair sports teams. All of the participants were competing in sporting events at a provincial or national level. All of the participants were training on a consistent basis. Informed consent was obtained from each participant. Individuals were excluded if they were being treated for any medical condition or injury that would impact their ability to complete the exercise and performance trials. Consent forms (Appendix I) and study procedures were approved by the University of Saskatchewan Biomedical Research Ethics Board (Appendix II) prior to data collection and testing. The participants were 6 males and 2 females, 24 to 45 years of age. Tables 1 and 2 provide descriptions of the participants, sport involvement and there sport specific classification. The research study used a cross-over design with the participants acting as their own controls. This design was chosen because wheelchair athletes have very unique characteristics dependent upon their level of SCI injury and/or nature of their physical disability. The participants that were included in this study had a wide variety of spinal cord injuries or physical disabilities. One of the primary goals of this research project was to maximize the internal validity of the study and to identify a relationship between the independent variable, CHO beverage, and the dependent variables of RER, HR, RPE, blood glucose, average speed and distance covered in the performance trial.

**Table 1 Participant Characteristics**

# code	Gender	Age (yr)	Disability	Body weight (kg)	Height (cm)	BMI
1	Male	45	SCI, T4	79.2	165	29.1
2	Male	28	CP	71.9	168	25.3
3	Female	27	SCI, T1	52.8	151	23.1
4	Male	24	SCI, L1	92.7	180	28.6
5	Male	43	SCI, T3	84.1	189	23.6
6	Male	44	SCI, C6	68.0	182	20.5
7	Male	41	SCI, C 5-6	90.7	188	25.7
8	Female	34	SCI, T12-L1	88.6	185	25.0
Mean $\pm$ SD		36 $\pm$ 8.5		78.5 $\pm$ 13.7	176 $\pm$ 13	25.1 $\pm$ 2.8

Information is presented for each participant, thoracic (T), cervical (C), lumbar (L), cerebral palsy affecting all four limbs (CP). Values are means  $\pm$  SD (n=8).

**Table 2 Participant Characteristics**

# code	Years Since Injury	<sup>¥</sup> Sport Classification	Sport(s)	Number of Years for Sport Involvement
1	23	Class 1	Basketball, waterskiing	20, 18
2	28	Class 0.5	Basketball, speed swimming	13
3	22	Class 1	Basketball, track, skiing	13
4	0.5	Not known	Track, weight training	1 month
5	8	Class 1	Basketball, waterskiing	2, 3
6	25	Class 1	Rugby	23
7	23.5	Class 0.5	Rugby, hand-cycling, alpine ski	14, 5
8	7	Not known	Swimming	3

Information is presented for each participant. <sup>¥</sup>Sport classifications are from International Wheelchair Basketball Federation and International Wheelchair Rugby Federation. Class 0.5 having higher level of SCI compared to Class 1.0 in sport classification.

## 2.2 Experimental Design

The research project involved three testing stages. The first visit involved the completion of the consent form, the physical activity readiness questionnaire (PAR-Q) and a participant medical history form to determine current health status and medications. Copies of these forms can be found in Appendix III. The PAR-Q is a 1-page questionnaire for people 15 to 69 years of age. It is used to assess whether individuals are physically ready to take on an exercise program. The first visit also included collection of body composition data using dual-energy x-ray absorptiometry (DXA),  $\text{VO}_{2\text{peak}}$  testing, and distribution of the modified 3-day food and exercise records. A 3-day food and exercise record modified for high performance athletes was used to control for the participant's dietary intake and monitor activity level between the two exercise and performance trials. The 3-day modified food and activity record can be found in Appendix IV. The body composition information was used to determine percent body fat (%BF) and fat free mass (FFM). The participants'  $\text{VO}_{2\text{peak}}$  was determined using an adapted stationary hand cycle suited for wheelchair athletes. The first visit was also used as a familiarization trial and for setting the exercise intensity standards for the exercise and performance trials. The participants were randomly assigned under double blind conditions into two groups. Group 1 received the treatment during the first exercise trial and group 2 received the treatment during the second exercise trial.

The second visit took place within approximately 7 days of the familiarization and maximal  $\text{VO}_2$  testing visit. The second and third visits included an exercise trial at 65%  $\text{VO}_{2\text{peak}}$  for 1 hour followed immediately by a 30-minute performance trial. All of the exercise and performance trials were conducted on the same adapted stationary hand cycle as the  $\text{VO}_{2\text{peak}}$ . The second and third visits were held one week apart. During the performance trial

the participants were instructed to cover as much distance as possible. Blood glucose and blood lactate were measured before the exercise trial and at 20-minute intervals during the 1 hour 65%  $\text{VO}_{2\text{peak}}$  trial. The 8% CHO treatment and placebo beverages were provided during the 1 hour 65%  $\text{VO}_{2\text{peak}}$  trial in 200 ml dosages at 15, 30, 45, and 60 minutes. A total of 800 ml of fluids were provided during the 1 hour 65%  $\text{VO}_{2\text{peak}}$  trial, providing 64 total grams of CHO. No beverages were provided during the 30-minute performance trial.

The physiological and metabolic impact of the moderate intensity exercise trial and performance trial was assessed through the collection of respiratory gases using a metabolic cart (Sensormedic Vmax 29 series; Anaheim, CA). Blood glucose and lactate were monitored immediately after the 30-minute performance trial and at 2, 5, and 10 minutes after the trial. Borg's RPE scale was administered every 20 minutes during the 60-minute trial and immediately after the 30-minute performance trial. The final dependent variables that were analyzed were the performance measures of total distance (km), average speed ( $\text{km}\cdot\text{hr}^{-1}$ ) and maximum speed ( $\text{km}\cdot\text{hr}^{-1}$ ) achieved during the performance trial. These variables were compared between the exercise trials to identify any significant difference attributed to the 8% CHO beverage consumption. A full diagram of the experimental design can be found in Appendix V.

### **2.2.1 Details of Anthropometric and Body Composition Collection**

Collection of anthropometric and body composition data including body mass (kg), height (cm), skinfolds, and DXA took place during the first visit. Body mass was determined using a platform scale that measured mass to the nearest 0.05 of a kilogram. Arm span was used as an indirect measure of height and was measured to the nearest centimetre (Mahan &

Escott-Stump, 2000). Arm span was measured while the participants were in a seated position. Skinfold measures were taken from four sites on the right side of the body; specifically, biceps, triceps, suprailiac, and subscapular. The skinfold calipers that were used were Harpenden skinfold calipers (Baty International, West Essex, England). Each site was measured three times. The mean skinfold thickness score was used for analysis. The Durnin and Wommersley equation was used to determine the percent body fat (Durnin & Wommersley, 1974). These sites were selected based on a study by Wells & Hooker (1990) who found that these sites were the most appropriate when assessing body composition of athletes with an SCI.

The DXA scan is a non-invasive test, which provides precise measurements of bone density, lean tissue mass, and total and regional body fat. Upon arrival for the DXA scan (Hologic Discovery QDR series Hologic Inc., Bedford, MA) the participants were asked to remove any metal accessories as these would impact the accuracy of the scan. Participants were instructed to lie in a prone position with the legs and arms extended as much as possible. One whole body scan was conducted for each participant. A technician carried out each DXA scan. The DXA unit uses very low dose x-rays of two different levels to distinguish between bone and soft tissue. DXA has been used to assess the body composition of wheelchair athletes in previous research (Mojtahedi, Valentine, & Evans, 2009; Maggioni, Bertoli, Margonato, Merati, Veicsteinas & Testolin, 2003). Mojtahedi et al. (2009) used the DXA scan as a reference method in comparison to skinfold and bioelectrical impedance analysis (BIA) with a group of 16 athletes with an SCI. They reported that DXA has been shown to be an accurate method for assessing body composition in this population (Mojtahedi et al., 2009). Jones et al. (1998) used DXA to assess changes in body composition in males with paraplegia.

They stated that DXA can be used to quantify body composition accurately in SCI participants (Jones et al., 1998).

### **2.2.2 Details of 3-day Food and Activity Records**

The primary goal of the 3-day food and activity records was to control for training and food intake leading into both exercise and performance trials. The participants were asked to maintain their normal training schedule and food intake patterns prior to and during the research study. The 3-day food and activity record can be found in Appendix IV. The participants were provided with verbal instructions by a registered dietitian on how to complete the 3-day food and activity records. The 3-day food record was modified to meet the needs of an athlete, by increasing space for recording larger portions, allowing more space for snack foods and fluids, and including questions regarding supplement use (Lun, Erdman, Reimer, 2009). The 3-day food record had been developed and used to collect dietary data from Canadian athletes (Lun et al. 2009) Developing the 3-day food records specific to participant needs was done in an effort to reduce the likelihood of error when completing the record (Block & Hartman, 1989). Previous researchers have used a one meal record and a 3-day food record as their dietary control (Spendiff & Campbell, 2003, 2004, 2005). The methods used in this research study imposed more control over dietary intake and physical activity, the rationale being that glycogen content may be impacted by an individual's food/fluid intake and physical activity in the days leading up to and between the exercise trials. The participants were asked to record their complete intake in detail, time consumed, amounts, types of foods, brand names, types of fluids, for the three days prior to the first exercise trial. The record was then used as a guide for three days prior to the second exercise

trial. The food records were analysed using FUEL 2.3b standard software (LogiForm International Inc., Saint-Foy, Quebec, Canada) for total energy content, carbohydrates, protein, fats and total fluids by a registered dietitian. The FUEL software has been used in previous published research to assess energy and macronutrient intake (Belanger & Boulay, 2005; Bruner, Chad, & Chizen, 2006).

The 3-day activity record was used to control for physical activity between the exercise trials and not for an estimation of energy expenditure. The participants were asked to record any physical activity conducted during the three days prior to the exercise and performance trial. They were then provided with a copy of their 3-day record, and they were encouraged to follow the same activity patterns prior to the second exercise and performance trial.

### **2.2.3 Protocol for the Maximal Oxygen Uptake Test ( $\text{VO}_{2\text{peak}}$ )**

Each participant's  $\text{VO}_{2\text{peak}}$  was measured using a stationary adapted hand bike (Varna II with a Cateye Tomo XC, CC-ST200 bike computer; Garbiola Island, BC, Canada). Expired gases were collected using a metabolic cart (Sensormedic Vmax 29 series; Anaheim CA). The resistance on the bike was held constant for all participants. After a 5-minute warm up, the  $\text{VO}_2$  protocol started at an initial velocity of  $4 \text{ km} \cdot \text{h}^{-1}$  for 1 minute and then increased by  $1 \text{ km} \cdot \text{h}^{-1}$  every minute until exhaustion. The speed ( $\text{km} \cdot \text{h}^{-1}$ ) was measured with the Cateye bike computer. Heart rate,  $\text{VO}_2$  and  $\text{VCO}_2$  were continuously monitored throughout the testing protocol. Pre and post lactate tests were also taken. Criteria used to determine if  $\text{VO}_{2\text{peak}}$  was attained were a RER ( $\text{VCO}_2 \cdot \text{VO}_2^{-1}$ ) level above 1.10, a heart rate that meets or exceeds 95% of their age-predicted heart rate maximum of  $220 - \text{chronological age}$  (Vinet et al. 2002), and participant inability to sustain the required velocity despite verbal encouragement (Fukuoka,



Endo, Kagawa, Itoh, & Nakanishi, 2002). Exhaustion was noted as the point at which the participant could not maintain the speed ( $\text{km} \cdot \text{h}^{-1}$ ). The participants were also familiarized with the testing procedures for both blood glucose and blood lactate during the  $\text{VO}_{2\text{peak}}$  testing.

#### **2.2.4 Protocol used for Group Assignments**

A research assistant, otherwise not involved with the research project, coded the participants by number. The code system was kept blind to the primary researcher until the completion of data collection and statistical analysis. The participants were separated by gender and then each gender was placed into two groups by random selection under double blind conditions. The participant codes were then drawn at random. The participants were then placed into either group one or group two. This method was used to ensure that the gender distribution was equal between both groups. Previous research has found that the hormonal fluctuations that occur during the female menstrual cycle may impact glycogen utilization during exercise. The female participants were asked about their menstrual cycle in order to account for the impact of hormonal fluctuations. Half of the group ( $n=4$ ) received the treatment first and the other half ( $n=4$ ) received the placebo first. The placebo was used to increase the internal validity of the research study, as it evaluated whether the observed effect is produced by the treatment or psychological effect (Thomas, Nelson, & Silverman, 2005). The two exercise trials were held approximately seven days apart ( $7 \pm 1$  day).

#### **2.2.5 Carbohydrate Beverage Protocol**

A research assistant, not otherwise involved in the study, measured the treatment and placebo powders to ensure that neither the researcher nor the participants were aware of the

beverage composition. The CHO beverage was 200 ml of an 8% CHO (8 g of CHO per 100 ml of water) ingested every 15 minutes during the 1 hour trial (at the 15, 30, 45, 60 minute mark) for a total of 64 g of CHO. The total composition for the 800 ml of 8% CHO beverage was 42.2 g sucrose, 21.1 g glucose, 448 mg sodium, and 139 mg potassium (Orange, Gatorade, Pepsico, Inc.). The placebo beverage contained 1.6 g sucrose, 160 mg sodium and 48 mg potassium per 800 ml. The placebo beverage was the same color and contained a non-caloric sweetener, sucralose (Orange, Nestea Acitv, Splenda© brand). The CHO and placebo beverage were matched for taste to the best of our ability. An 8% CHO was used based on previous research by Spendiff and Campbell (2004) in which they used a 7.6% CHO solution (7.6 g of CHO per 100 ml water), a total 49 g of CHO, and found a non-significant performance benefit. The protocol utilized in this study provided a greater volume of beverage and a greater amount of CHO than previous work. This increased dosage addresses the limitations noted from the Spendiff and Campbell (2004) study in an attempt to enhance the effect on the performance measure. The 8% CHO beverage that was provided in 200 ml dosages every 15 minutes was also designed to meet the upper limits of the 2000 ACSM, ADA, DC carbohydrate guidelines for able-bodied athletes of 30 to 60 g CHO per hour (approximately  $0.7 \text{ g CHO} \cdot \text{kg}^{-1} \cdot \text{h}$ ). An ideal CHO dosage has yet to be determined for wheelchair athletes. The high end of the dosage range was also used because previous research conducted with individuals with SCI has noted that fat oxidation is limited during aerobic exercise (Astorino & Harness, 2009). The dosage would provide  $0.9 \pm 0.2 \text{ g CHO} \cdot \text{kg}^{-1}$ , which exceeds the recommendations; however, this dose was the only fuel source for the 60-min exercise and 30-minute performance trial. No feeding occurred during the performance trial.

### **2.2.6 Pre-Exercise Meal Protocol**

The participants were asked to report to the test site at the same time on both occasions following a macronutrient-controlled meal that provided between 2 g CHO·kg<sup>-1</sup> according to the IOC pre-exercise recommendations. Each participant was provided with a detailed list of what to consume in regards to certain food portions to meet their CHO needed based on their current body weight. Examples of pre-exercise meals are found in the Appendix VI. The macronutrient-controlled meal was consumed 3 hours prior to the exercise test. This protocol helped ensure that the participants were not starting in a fasted state, which may have led to premature fatigue and decreased baseline blood glucose levels.

### **2.2.7 Expired Gas Collection and Blood Sample Analysis**

Expired gases were collected at 5-minute intervals during the 60-minute exercise trial 65% VO<sub>2peak</sub> (0-5 min, 15-20 min, 30-35 min, 40-45 min, 55-60 min) and continuously during the 30 minute performance trial. Total CHO and fat oxidation (g·min<sup>-1</sup>) was calculated using the following equations (Jeukendrup & Wallis, 2005);

$$\text{Total CHO oxidation (g·min}^{-1}\text{)} = 4.210\text{VCO}_2 - 2.962\text{VO}_2$$

$$\text{Total fat oxidation (g·min}^{-1}\text{)} = 1.695\text{VO}_2 - 1.701\text{VCO}_2$$

Respiratory exchange ratio was calculated during the exercise and performance trials as the ratio between the volume of CO<sub>2</sub> expired and the volume of O<sub>2</sub> consumed.

Heart rate was monitored throughout the trial using both the metabolic cart and a Polar watch monitor (Polar CE0537, Polar Electro OY, Finland). Blood glucose and blood lactate were measured prior to the exercise trial, at 20 min interval during the 65% VO<sub>2peak</sub> exercise phase, immediately post and at 2, 5 10 min after the 30-minute performance trial. A fingertip,

selected by the participant, was first cleaned with an alcohol swab. The fingertip was then pricked and a drop of blood was put on a glucose test strip and a subsequent drop on a lactate test strip. Samples were subsequently assessed for glucose using a One Touch® Ultra Mini™ portable glucometer (LifeScan/ Johnson & Johnson, Milpitas, CA, USA) and for lactate using the Lactate Pro, portable lactate meter (Arkray, Inc., Kyoto, Japan). The glucose One Touch Ultra® test strips that were used can measure blood glucose levels in the range of 0.6 to 33.3 mmol.l<sup>-1</sup> (according to manufacture specifications). A meter that can read low blood glucose values is critical when monitoring values during exercise using a placebo non-caloric beverage because hypoglycaemia could occur (<2.5 mmol.l<sup>-1</sup>). The blood glucose meters and testing strips were selected because they are portable and requires only a small (0.6 µl) quantity of blood.

The Lactate Pro was used because it requires a small sample of blood; only 5 µl is needed on the reagent strip. Pyne, Boston, Martin, and Logan (2000) evaluated the reliability and versatility of the Lactate Pro analyser with elite athletes from the Australian Institute of Sport. The correlation between the Lactate Pro and the ABL 700 Series Acid-Base analyser, considered to be the criterion instrument, was  $r = 0.98$ . The correlation between two Lactate Pro analysers on the same sample ( $n = 96$  cases) was  $r = 0.99$  (Pyne et al., 2000). Pyne et al. also noted that the Lactate Pro can analyse a sample and display the results approximately 30 seconds quicker than other portable lactate monitors, which makes it more desirable for field testing. The Lactate Pro has been used with this population in previous research (Goosey-Tolfrey, Foden, Perret, & Degens, 2008). All analysers were calibrated and operated in accordance with manufacturer's instructions.

### 2.2.8 Exercise and Performance Trial

All the participants completed the same exercise and performance trial. The exercise and performance trial was conducted on an adapted stationary hand cycle. A full diagram of the exercise, CHO feeding and sample collection protocol can be found in Appendix V. The exercise trial was 1 hour at 65%  $\text{VO}_{2\text{peak}}$  followed immediately by a 30-minute performance trial in which distance covered (km), average speed ( $\text{km}\cdot\text{h}^{-1}$ ) and maximum speed ( $\text{km}\cdot\text{h}^{-1}$ ) were measured. This exercise protocol was different from that used in previous research. Prior studies included a 5-minute rest between the one hour exercise trial and the performance trial. This change in protocol ensured that the exercise and performance trial were more consistent with real world sport competitions, in which no breaks are provided prior to the finishing sprint or increase in intensity. An exercise intensity of 65%  $\text{VO}_{2\text{peak}}$  was chosen because it has been shown to elicit an increase in the reliance on CHO as the primary fuel source during wheelchair racing (Knechtle, Muller, Willmann, Eser & Knecht, 2004). Also, Spendiff and Campbell (2004) noted that exercise trials at intensities above 65%  $\text{VO}_{2\text{peak}}$  might result in premature fatigue during the 1-hour trial. The performance trial was set at 30 minutes to reflect the participant's competitive events. Most of the cross country ski competitions occur over 30 to 50 minutes, wheelchair basketball is played over four 10-minute quarters, and wheelchair racing athletes compete in sprint events (100 m, 200 m, 400 m), middle distance (800 m, 1500 m), and long distance (5,000 m, 10,000 m) events. Depending on the participant's fitness level the 10,000 m wheelchair event can take between 30 to 40 minutes. Previous research also stated that results in a longer performance trial, more than 20 minutes, might be impacted to a greater degree by CHO feedings (Spendiff & Campbell, 2005).

Borg's scale of rating of perceived exertion was also administered at the 20, 40, 60-minute mark of the 65%  $\text{VO}_{2\text{peak}}$  exercise trial and at the completion of the 30-minute performance trial. Borg's scale of RPE is a 15-grade scale of perceived exertion, with values from 6 to 20. The RPE scale is a widely accepted means of estimating exercise intensity in adults (Lamb, Eston, & Corns, 1999). A rating of 6 to 7 on the scale corresponds to a very, very light effort, and a rating of 19 to 20 indicates an RPE of very, very hard effort (Borg, 1982). "The overall perceived exertion rating integrates various information, including the many signals elicited from the peripheral working muscles and joints, from the central cardiovascular and respiratory functions, and from the central nervous system" (Borg, 1982, p.377). The RPE scale correlates with heart rate ( $r = 0.80$  to  $0.90$ ) (Borg, 1982).

### **2.3 Statistical Analysis**

Sample size was calculated using a power of 80% and the effect size of 0.72 noted from the performance measures of a study conducted with a similar population group (Spendiff & Campbell, 2003). A sample of 15 participants was needed to have sufficient statistical power. Sixteen participants were initially recruited. Four participants did not complete the study due to their work schedule. Two participants had to withdraw after the body composition testing due to pre-existing injuries not related to the study. Two participants did not live in Saskatoon and the time and travel commitments for the exercise and performance testing was too much of a time commitment. Eight participants completed all of the components of the research study.

The impact of the independent variable, CHO beverage consumed, on the dependent variables (RER, HR, blood lactate, blood glucose, and RPE) between the exercise trials was

analyzed for significance using a two factor repeated measures ANOVA. The statistical analysis program used in the current study was SPSS 16.0 (SPSS Inc. Headquarters, Chicago, IL). If there was a violation of sphericity, the Greenhouse-Geisser values were used. T-tests with bonferonni adjustments were used for post hoc analysis when needed. A dependent *t*-test was used to analyze the performance measure, distance covered, between the two 30-minute performance trials. Dependent *t*-test was also used to test for an order effect between the two trials. A significance of  $p < 0.05$  was used.

## CHAPTER 3

### 3. RESULTS

#### 3.1 Body Composition

As evident in Table 3, % BF did not differ significantly across the two methods of measurement (DXA and skinfold measures) of determination,  $t(7) = -1.905$ ,  $p=0.099$ .

**Table 3- Body Composition Data**

# Code	% BF- skinfold	DXA- % BF	DXA LBM (kg)	BMD ( $\text{g}\cdot\text{cm}^2$ )
1	34.3	33.6	48.3	1.23
2	21.3	23.4	52.2	1.17
3	32.5	36.9	30.4	1.83
4	27.8	26.8	63.5	1.25
5	21.3	24.0	63.2	1.53
6	13.6	13.4	52.4	1.16
7	32.3	32.9	55.0	1.10
8	31.5	38.5	49.7	1.26
Means ± SD	26.8 ± 7.3 (M) 25.1 ± 7.1 (F) 32.1 ± 0.5	28.7 ± 8.4 (M) 25.7 ± 6.8 (F) 37.7 ± 0.8	51.8 ± 10.4 (M) 55.8 ± 5.7 (F) 40.1 ± 9.7	1.32 ± 0.24 (M) 1.24 ± 0.14 (F) 1.55 ± 0.28

Lean body mass (LBM), percent body fat (% BF), bone mineral density (BMD). Means ± SD are presented for the group (n=8) and by gender, females (F) (n=2), males (M) (n=6).

#### 3.2 Three Day Food Records

Results from the modified food records are presented in 3-day averaged values (Table 4). Total caloric intake and caloric intake per kg body weight are presented for each participant. Data presented from the 3-day food records were compared to, ADA, ACSM, and DC (2000) guidelines. Only 25% of the participants met the daily caloric recommendations for active adults (active =  $37$  to  $41 \text{ kcal}\cdot\text{kg}^{-1} \text{ body weight}\cdot\text{d}^{-1}$ ). Macronutrients were analysed relative to body weight ( $\text{g}\cdot\text{kg}^{-1}\text{body weight}\cdot\text{d}^{-1}$ ) and compared to current able-bodied athlete and active adult guidelines. Carbohydrate



recommendations of 6 to 10 g·kg<sup>-1</sup> body weight·d<sup>-1</sup> were not met by any of the participants. Protein recommendations for able-bodied athletes and active adults of 1.2 to 1.7 g·kg<sup>-1</sup> body weight·d<sup>-1</sup> were met by 63% of the participants. Average caloric intake from fat (31%) exceeded current recommendations of 20-25% total energy intake. Total fluid intake was below gender specific recommendations of 3,700ml for males and 2,700ml for females. The participants were also asked to report their supplement use. Three of the participants reported taking supplements including: multivitamins, vitamin D, E, and folic acid.

**Table 4- Three-day Food Record Values**

# Code	kcal intake	kcal·kg <sup>-1</sup> BW	CHO g·kg <sup>-1</sup> BW	Protein g·kg <sup>-1</sup> BW	% kcal fat	Total fluids (ml)
1	2622	33	4.20	1.12	35	2047
2	2779	38.6	4.10	1.87	39	2167
3	1629	31	4.26	1.49	27	1517
4	2749	29.7	4.17	1.56	21	2787
5	3096	36.5	4.65	1.92	30	1978
6	2740	40.3	4.82	2.18	30	3660
7	1808	20	2.41	0.83	37	2383
8	2086	23.6	3.53	0.76	29	2683
Mean ± SD	2438 ± 528	31.6 ± 7.1	4.02 ± 0.75	1.46 ± 0.52	31 ± 5.8	2403 ± 650

Information is presented for each participant. Energy (kcal), macronutrients and total fluids are presented. Values are means ± SD (n=8). Data presented are 3-day averaged results.

### 3.3 Maximal Exercise Measures

The average VO<sub>2peak</sub> achieved was 1.49 ± 0.49 l·min<sup>-1</sup>, and average heart rate, RER and CHO oxidation achieved at peak were 145 ± 27 bpm, 1.25 ± 0.103 and 3.38 ± 1.12 g·min<sup>-1</sup> respectively. Lactate at pre-test and at the completion of the maximal effort was 1.45 ± 0.5 mmol.l<sup>-1</sup> and 7.35 ± 2.33 mmol.l<sup>-1</sup>. The results are presented for each participant in Table 5.

**Table 5- Participants' Resting Heart Rate Values and Maximal VO<sub>2peak</sub> Testing Values**

#	Resting HR	Max HR	Max Speed (km·h <sup>-1</sup> )	Pre-lactate (mmol.l <sup>-1</sup> )	Post-lactate (mmol.l <sup>-1</sup> )	VO <sub>2 peak</sub> (l·min <sup>-1</sup> )	VO <sub>2peak</sub> (ml·kg·mi n <sup>-1</sup> )	RER
1	84	171	17	1.9	12.9	1.728	22.6	1.36
2	78	171	12	1.3	5.8	1.993	27.7	1.13
3	90	120	12	0.8	7.7	0.988	18.7	1.24
4	83	171	18	1.6	8.2	2.469	26.6	1.21
5	81	165	14	1.8	6.7	1.295	15.4	1.37
6	70	109	11	1.1	5.0	1.128	16.5	1.07
7	71	108	11	1.0	5.6	1.135	12.5	1.25
8	70	148	11	2.4	6.9	1.196	13.5	1.35
	78.4 ± 7	145 ± 27	13 ± 2.6	1.5 ± 0.5	7.4 ± 2.3	1.49 ± 0.49	19.2 ± 5.5	1.25 ± 0.10

Information is presented for each participant. Heart rate (HR), respiratory exchange ratio (RER). Values are expressed as means ± SD (n=8).

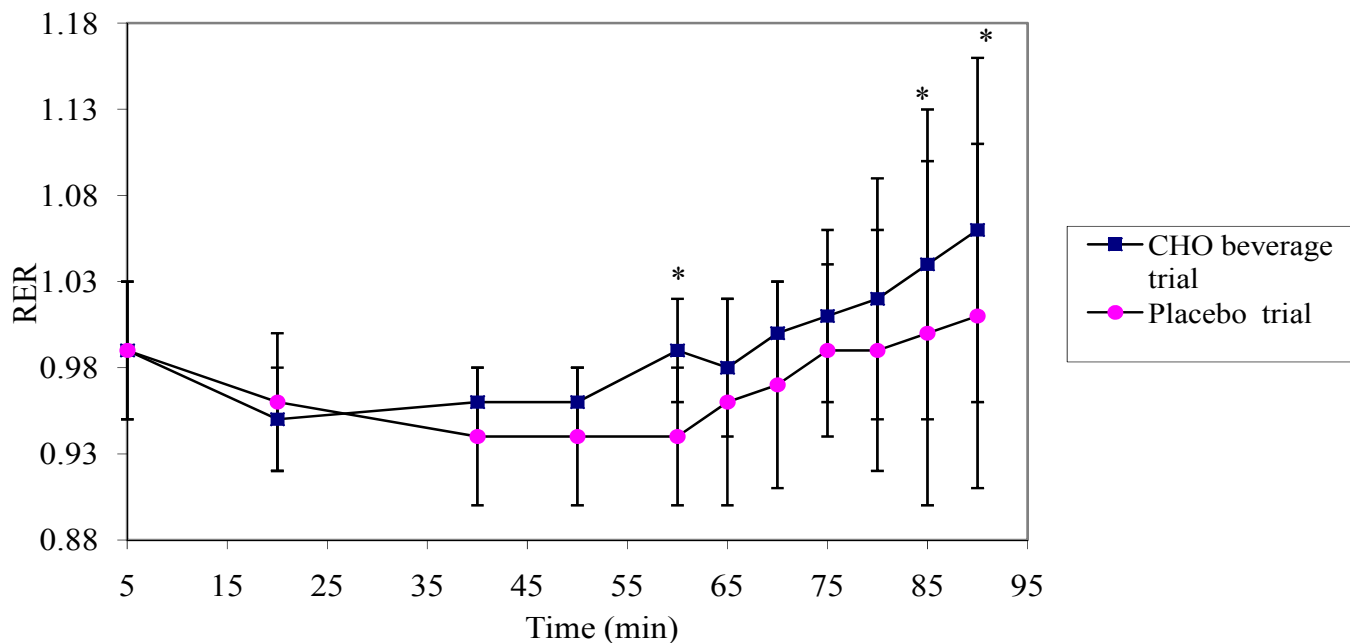
### 3.4 Menstrual Cycle Timing

Both female participants completed the CHO beverage exercise trial during the luteal phase and the placebo exercise trial during the follicular phase. Participant 3 conducted the CHO beverage trial on day 28 of her menstrual cycle and the placebo trial on day 7 of her menstrual cycle. Participant 8 conducted the CHO beverage trial on day 25 of her menstrual cycle and the placebo trial on day 4 of her menstrual cycle. Carbohydrate ingestion did not enhance the performance of either athlete and their results followed the same trend as the male participants. Therefore the mean values presented are not separated by gender.

### **3.5 Exercise Trial Physiological Measures**

#### **3.5.1 Respiratory Exchange Ratio (RER)**

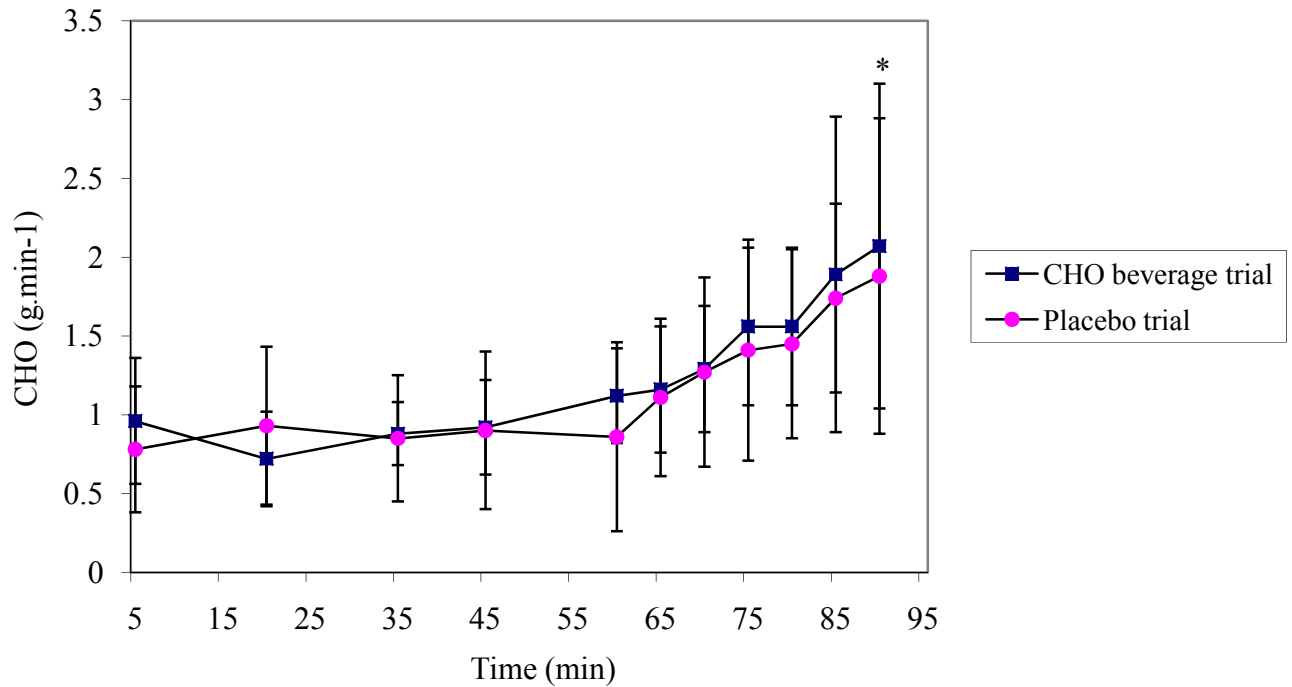
During the 60-minute exercise trial there was a significant interaction between beverage and time,  $F(1.712, 11.985) = 5.55$   $p=0.023$ . RER values were significantly higher in the CHO beverage trial during the final collection period of the 60-minute exercise trial (55-60 minutes). For the performance trial there was a significant beverage by time interaction,  $F(5,30) = 3.22$ ,  $p=0.019$ . During the final 10 minutes of the performance trial RER values were also significantly higher during the CHO beverage trial versus the placebo trial  $p<0.05$ . Individual RER values can be found in Appendix IX. Mean values are presented in Figure 1 and Table 6.



**Figure 1.** Mean Respiratory exchange ratio (RER)  $\pm$  SD values during the collection periods, 0-5 min, 15-20 min, 30-35 min, 40-45 min, 55-60 min for the 60-min exercise trial ( $n=8$ ). Collection periods were 5-min averages during the 30-min performance trial. \* Indicates that the CHO beverage trial RER values were significantly higher during the 55-60-min collection period and the last 2 collection periods of the performance trial (20-25 minutes and 25-30 minutes) ( $p<0.05$ ). For the final collection period, 85 to 90-min ( $n=7$ ).

### 3.5.2 Carbohydrate Oxidation ( $\text{g} \cdot \text{min}^{-1}$ )

For the 60-minute exercise trial, there was no significant main effect of the beverage and no significant main effect of time ( $p=0.087$ ). There was no significant beverage by time interaction ( $p=0.062$ ). For the 30-minute performance trial there was a significant beverage by time interaction,  $F(5,30)=3.862$ ,  $p=0.022$ . Post hoc analysis revealed that there was a significant difference in CHO oxidation values during the last 5 minutes of the performance trial,  $t(6)=3.884$ ,  $p=0.008$ . The CHO beverage trial resulted in a higher oxidation value ( $2.07 \pm 1.02$ ) vs. the placebo trial ( $1.88 \pm 1.01$ ). The data points are presented in Figure 2.



**Figure 2.** Average carbohydrate (CHO) oxidation ( $\text{g} \cdot \text{min}^{-1}$ )  $\pm$  SD values during the collection periods, 0-5 min, 15-20 min, 30-35 min, 40-45 min, 55-60 min for the 60-min exercise trial ( $n=8$ ). Collection periods were 5-min averages during the exercise and performance trial. For the final collection period, 85 to 90-min ( $n=7$ ). \* Indicates the CHO beverage trial resulting in significantly more CHO oxidation during the last 5 minutes of the performance trial ( $p<0.01$ ).

### 3.5.3 Oxygen Uptake ( $\text{VO}_2$ )

For the 60 minute exercise trial there was a significant effect of time,  $F(4,28)=15.77$ ,  $p=0.00$ . There was no main effect of beverage and no significant interaction ( $p=0.257$ ). For the performance trial there was a significant effect of time,  $F(1.168,7.006)=14.31$ ,  $p=0.006$ . There was no significant main effect of beverage and no significant beverage by time interaction ( $p=0.296$ ). The values are presented in Table 6. The percent  $\text{VO}_{2\text{peak}}$  values are presented per participant for the 60-minute exercise portion and 30-minute performance trials are presented in Appendix VIII.

**Table 6- Physiological values collected during the 60-minute exercise (5-min time period averages) and 30-minute performance trial (continuous sampling, 5-min averages) for CHO beverage trial and placebo beverage trial.**

Time	VO <sub>2</sub> (l·min <sup>-1</sup> ) <sup>#</sup>		RER		CHO oxidation (g·min <sup>-1</sup> )		Fat oxidation (g·min <sup>-1</sup> )	
	CHO	Placebo	CHO	Placebo	CHO	Placebo	CHO	Placebo
0-5 min	0.78 ± 0.2	0.73 ± 0.2	0.99 ± 0.04	0.99 ± 0.04	0.96 ± 0.4	0.92 ± 0.4	0.02 ± 0.03	0.14 ± 0.03
15-20 min	0.79 ± 0.2	0.82 ± 0.3	0.95 ± 0.03	0.96 ± 0.04	0.83 ± 0.3	0.93 ± 0.5	0.06 ± 0.03	0.12 ± 0.02
30-35 min	0.83 ± 0.2	0.84 ± 0.3	0.96 ± 0.02	0.94 ± 0.04	0.88 ± 0.2	0.85 ± 0.4	0.06 ± 0.02	0.07 ± 0.04
40-45 min	0.85 ± 0.2	0.89 ± 0.3	0.96 ± 0.02	0.94 ± 0.04	0.92 ± 0.3	0.90 ± 0.5	0.05 ± 0.04	0.08 ± 0.05
55-60 min	0.93 ± 0.3	0.94 ± 0.3	0.99 ± 0.03*	0.94 ± 0.04	1.12 ± 0.3	0.86 ± 0.6	0.03 ± 0.03	0.08 ± 0.04
Time-1	0.98 ± 0.3	1.03 ± 0.4	0.98 ± 0.04	0.96 ± 0.06	1.16 ± 0.4	1.17 ± 0.5	0.04 ± 0.04	0.04 ± 0.04
Time-2	1.06 ± 0.3	1.09 ± 0.4	1.00 ± 0.03	0.97 ± 0.06	1.33 ± 0.4	1.32 ± 0.6	0.03 ± 0.04	0.05 ± 0.04
Time-3	1.15 ± 0.3	1.12 ± 0.4	1.01 ± 0.05	0.99 ± 0.05	1.41 ± 0.5	1.44 ± 0.7	0.03 ± 0.03	0.03 ± 0.04
Time 4	1.14 ± 0.4	1.16 ± 0.4	1.02 ± 0.07	0.99 ± 0.07	1.36 ± 0.5	1.45 ± 0.6	0.03 ± 0.04	0.05 ± 0.06
Time 5	1.27 ± 0.4	1.29 ± 0.5	1.04 ± 0.09*	1.0 ± 0.10	1.64 ± 1.0	1.39 ± 0.6	0.02 ± 0.02	0.08 ± 0.07
Time 6	1.32 ± 0.5	1.32 ± 0.5	1.06 ± 0.10*	1.0 ± 0.10	2.07 ± 1.03*	1.88 ± 1.0	0.01 ± 0.02	0.02 ± 0.05

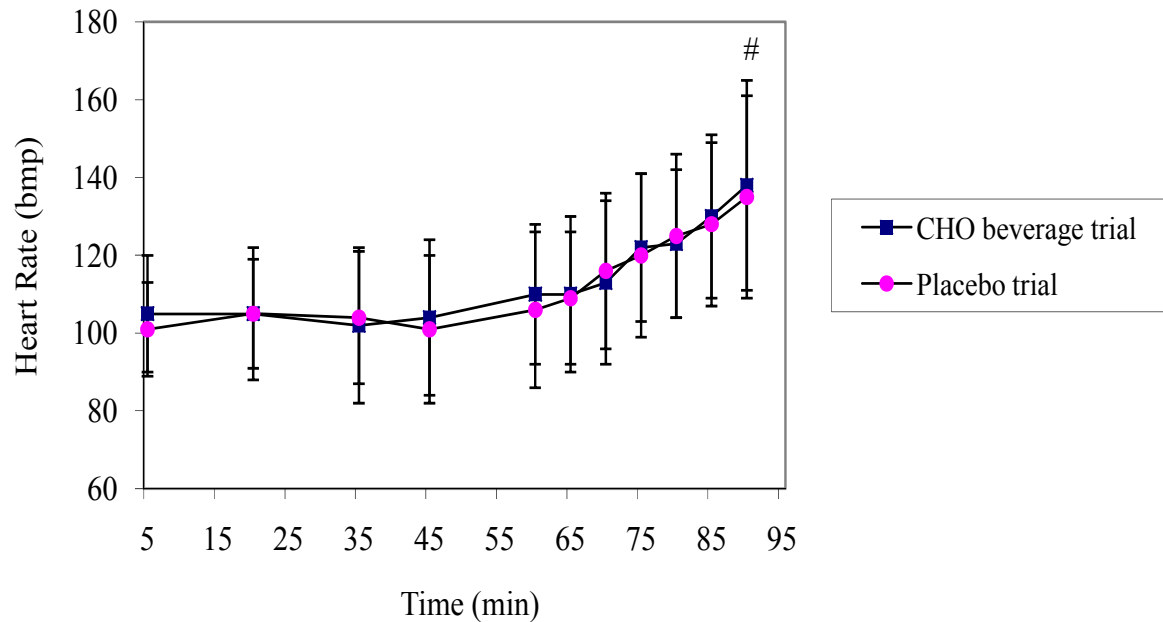
Values are presented as mean ± standard deviation. \*Indicates values were significantly higher in the CHO beverage trial vs. placebo trial ( $p < 0.05$ ). Values for 60-min exercise trial (n=8), for performance trial (n=7). # Indicates a significant increase in VO<sub>2</sub> values during the 60-minute exercise and 30 minute performance trial ( $p < 0.05$ ) but no significant differences between the beverage trials.

#### **3.5.4 Fat Oxidation ( $\text{g}\cdot\text{min}^{-1}$ )**

For both the 60-minute exercise trial and the 30-minute performance trial there was no significant interaction, main effect of time or main effect of drink (Table 6).

#### **3.5.5 Heart Rate**

During the 60-minute exercise trial there was no effect of beverage or time on heart rate and no significant interaction. At the end of the 60-minute exercise trial the average heart rate values were  $111 \pm 18$  bpm for the CHO beverage trial and  $106 \pm 20$  bpm for the placebo trial. For heart rate during the 30-minute performance trial there was a significant main effect of time,  $F(1.156, 6.938) = 11.994$ ,  $p = 0.009$ . An increase in heart rate over time during the performance trial occurred as expected. At the end of the performance trial the heart rate values were  $138 \pm 27$  bpm for the CHO beverage trial and  $134 \pm 26$  bpm for the placebo trial. Values are presented in Figure 3.



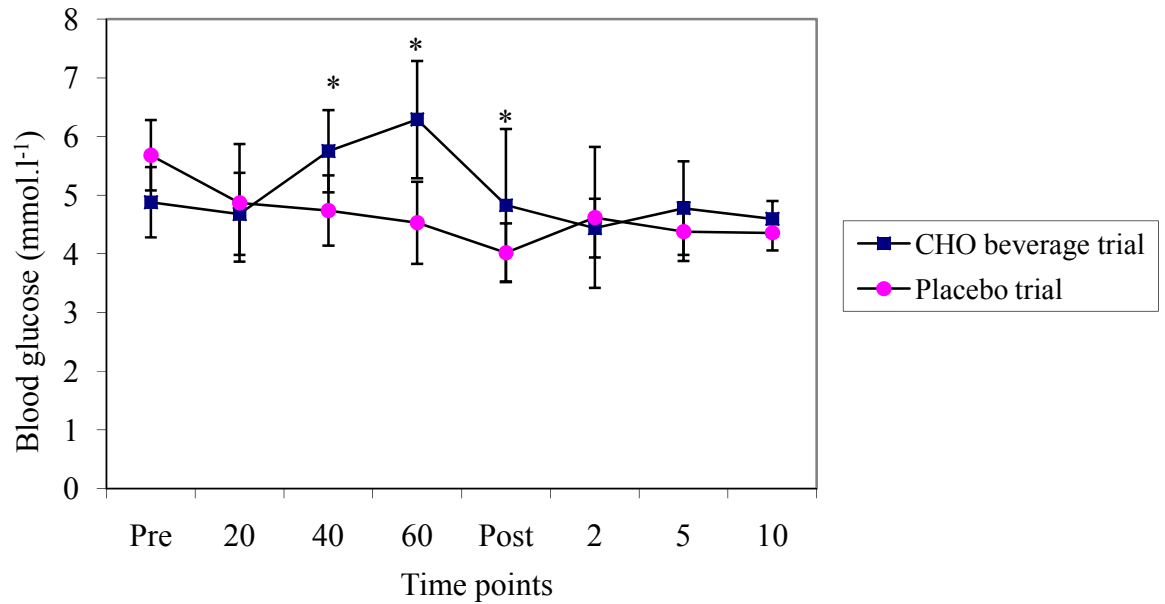
**Figure 3.** Average heart rate  $\pm$  SD values (bpm) during the collection periods, 0-5 min, 15-20 min, 30-35 min, 40-45 min, 55-60 min for the 60-min exercise trial ( $n=8$ ). Collection periods were 5-min averages during the 30-min performance trial. For the final collection period, 85 to 90-min ( $n=7$ ). There was no significant effect of time during the 60 minute exercise trial. # Indicates a significant increase in HR during the 30 minute performance trial ( $p=0.009$ ) but no significant differences between the beverage trials.

### 3.6 Finger Tip Capillary Blood Analyses

#### 3.6.1 Glucose ( $\text{mmol.l}^{-1}$ )

For the blood glucose values there was a significant beverage by time interaction for both the 60-minute trial and the performance test (Figure 4). The CHO beverage trial resulted in higher blood glucose values at 40 and 60 minutes and at the end of the performance test. At the end of the performance trial the values were significantly higher in the CHO beverage trial ( $p=0.008$ ), with  $4.83 \pm 1.26 \text{ mmol.l}^{-1}$  for the CHO beverage trial vs.  $4.03 \pm 0.49 \text{ mmol.l}^{-1}$  for placebo trial. Individual blood glucose values can be found in Appendix IX.





**Figure 4.** Mean blood glucose values (mmol.l<sup>-1</sup>)  $\pm$  SD collected at 8 time points (n=8), pre-exercise trial, at 20-min, 40-min, 60-min and then immediately post 30-minute performance trial, 2-min, 5-min and 10-min post. \* Indicates significantly higher blood glucose values in the CHO beverage trial vs. the placebo beverage ( $p < 0.05$ ).

### 3.6.2 Lactate (mmol.l<sup>-1</sup>)

For blood lactate values there was a significant main effect of time ( $p = 0.02$ ).

There was no significant main effect of beverage ( $p = 0.082$ ) and no significant beverage by time interaction ( $p = 0.537$ ). Lactate values are presented in Table 7. Individual lactate results can be found in Appendix IX.

### 3.7 Rating of Perceived Exertion (RPE)

During the exercise and performance trial, the RPE values increased over time, as was expected,  $F(3,21) = 60.78$ ,  $p < 0.001$ . There was no significant main effect of beverage ( $p = 0.339$ ) and no significant beverage by time interaction ( $p = 0.723$ ). Values are presented in Table 7.

**Table 7- Blood Lactate, Glucose and RPE values during the 60-minute exercise trial and post 30-minute performance trial**

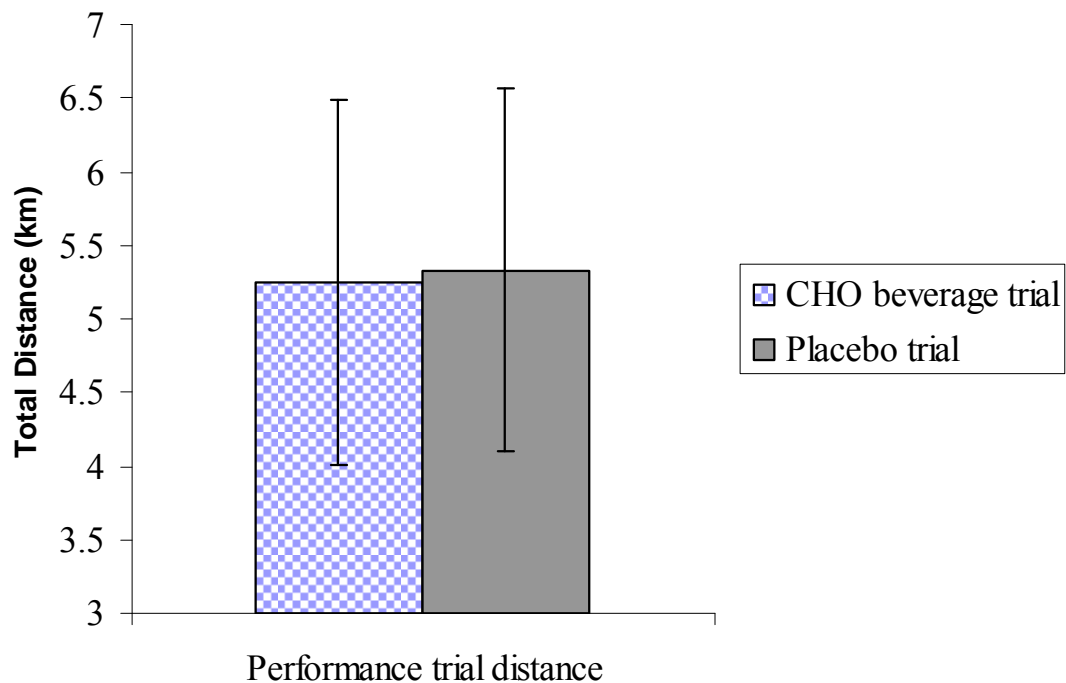
Time points	#Blood Lactate (mmol.l <sup>-1</sup> )		Blood Glucose (mmol.l <sup>-1</sup> )		#RPE values	
	CHO	Placebo	CHO	Placebo	CHO	Placebo
Pre-test	1.9 ± 0.8	1.5 ± 0.6	4.9 ± 0.6	5.7 ± 0.6		
20min	3.7 ± 2.0	4.3 ± 2.6	4.7 ± 0.7	4.9 ± 1.0	11.3 ± 1.6	11.5 ± 1.1
40min	4.1 ± 2.6	3.1 ± 1.6	5.8 ± 0.7*	4.7 ± 0.6	12.3 ± 1.6	12.8 ± 1.0
60 min	5.8 ± 6.8	3.7 ± 3.2	6.3 ± 1.0*	4.5 ± 0.7	13.1 ± 1.8	13.6 ± 1.7
Post Perf.	6.8 ± 2.9	7.2 ± 4.7	4.8 ± 1.3*	4.0 ± 0.5	18.5 ± 1.7	18.5 ± 1.8
2min post	7.7 ± 5.9	8.3 ± 7.8	4.4 ± 0.5	4.6 ± 1.2		
5min post	7.3 ± 4.4	6.0 ± 6.0	4.8 ± 0.8	4.4 ± 0.5		
10min post	4.6 ± 2.3	3.6 ± 2.2	4.6 ± 0.3	4.4 ± 0.3		

\* Indicates a significant difference between the 2 trials ( $p < 0.05$ ). RPE, rating of perceived exertion. # Indicates a main effect of time for blood lactate values and RPE ( $p < 0.05$ ). Values presented are means ± SD (n=8).

### 3.8 Exercise Performance Measures

There were no significant differences between the CHO beverage trial and placebo trial for distance covered (CHO beverage  $5.25 \pm 1.22$ , placebo trial  $5.32 \pm 1.26$  km), average speed (CHO beverage  $10.80 \pm 2.43$ , placebo trial  $10.90 \pm 2.43$  km·h<sup>-1</sup>), or maximal speed (CHO beverage  $14.43 \pm 3.45$ , placebo trial  $14.64 \pm 3.25$  km·h<sup>-1</sup>) during the 30-minute performance trial. There was a significant correlation between the two performance trials for total distance (km) ( $r = 0.994$ ). Those athletes that covered the greatest distance during the CHO beverage trial also achieved a greater distance during the placebo trial. One participant was not able to complete the full 30-minute

performance trial; he had to stop at 22:33.00 due to fatigue. Therefore the second performance trial was limited to 22:33.00 to ensure that performance measures could be compared. Total distance for the CHO beverage trial and placebo trial are presented in Figure 5. The performance distances are presented for each participant for the 60-minute exercise trial in Appendix VIII. Individual performance trial results can be found in Appendix IX.



**Figure 5.** Mean group distance  $\pm$  SD covered in 30-minute performance trial, no significant differences between trials. CHO beverage trial distance was  $5.25 \pm 1.22$  km, Placebo trial distance was  $5.32 \pm 1.25$  km ( $n=8$ ).

## **CHAPTER 4**

### **4. DISCUSSION**

Results from this study failed to demonstrate any significant differences between the CHO beverage and placebo for total distance (km), average speed ( $\text{km}\cdot\text{hr}^{-1}$ ) or maximum speed achieved ( $\text{km}\cdot\text{hr}^{-1}$ ) during the 30-minute performance trial following 1 hour of exercise at 65%  $\text{VO}_{2\text{peak}}$ . Only two of the eight participants covered more distance during the CHO beverage trial versus the placebo trial. We also found that the 8% CHO beverage did not result in lower RPE values during the exercise or performance trial. Our hypotheses that the CHO beverage would result in higher blood glucose and RER values in addition to greater CHO oxidation during the exercise and performance trial were supported. The results from the 3-day foods records indicated the participants were not meeting the current dietary recommendations for able-bodied athletes, the participants were within the AMDR and the RDAs for CHO and protein.

#### **4.1 Participant Characteristics**

Each individual with a SCI has a unique level of function directly associated with the nature and specific level of their spinal cord injury. The level of SCI, whether the injury is complete or incomplete and the nature of the resulting physical disability has a significant impact on the physiological response of the individual to exercise and overall physical capacity (Bhambhani, 2002). In a study examining 68 athletes with a variety of spinal cord injury levels and physical impairments van der Woude, Bouten, Veeger and Gwinn (2002) noted that physiological characteristics are highly variable even within participant groups with the same categorized injury levels due to individual

variations in neurological function, sport discipline and other personal traits. Therefore, it is important to recognize that making comparisons with data from the current study with others examining wheelchair athletes has numerous limitations. It is also important to note that one of the participants in the current study has cerebral palsy (CP) which has also been shown to affect maximal exercise capacity (van der Woude et al., 2002) but in a manner dissimilar to what would be expected for individuals with a SCI.

Measures of physical fitness, such as  $VO_{2peak}$ , are significantly reduced in persons with a SCI when compared to values observed in healthy age-matched non-SCI individuals. The magnitude of this decrease is directly dependent upon the level of SCI (van der Woude et al., 2002) and the consequent physiological and physical impairments that occur. With a SCI above T1, as seen with two of the participants in the current study, sympathetic stimulation to the myocardium is affected, which reduces the individual's maximal cardiac output leading to a reduction in overall oxygen transportation to the active tissue (Bhambhani, 2002). Other factors that lead to reduced  $VO_{2peak}$  are a reduction in active muscle tissue below the level of lesion which limits arteriovenous oxygen difference and increased venous pooling in the lower extremities due to the loss of muscle pump action. Decreased muscle pump action causes a reduction in stroke volume and cardiac output due to reduced venous return to the heart (Bhambhani, Burnham, Wheeler, Eriksson, Holland & Steadward, 1995).

Five of the participants in the current study had injury levels ranging from T1 to L1. Their level of injury may have also resulted in decreased stroke volume and cardiac output due to the above factors minus the absence of sympathetic innervation, which may help to explain the low maximal oxygen uptake values which were observed. These

participants had maximal heart rate values of  $155 \pm 19$  bpm and maximal  $\text{VO}_2$  values of  $19.4 \pm 4.8 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$ .

Although the participants in our study were trained athletes they did present, on average, with lower levels of fitness than might be expected as demonstrated by reduced  $\text{VO}_{2\text{peak}}$  values. Wells and Hooker (1990) stated that  $\text{VO}_{2\text{peak}}$  seems to be inversely related to the level of SCI, with the higher the SCI the lower the  $\text{VO}_{2\text{peak}}$ . These findings are supported by the results of the current study in that the two participants with quadriplegia had very low  $\text{VO}_{2\text{peak}}$  values of  $14.5 \pm 2 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$ . Bhambhani et al. (1995) reported maximal oxygen uptake values of  $19.8 \pm 4.3 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$  for endurance-trained male athletes with quadriplegia and studies specifically assessing athletes with paraplegia have demonstrated values 1.5 times greater than were observed in the current study (Price & Campbell, 1999). One key difference between the current study and the research done by Price and Campbell (1999) is the age difference of the participants. The mean age in the current study was  $36 \pm 8.5$  years versus  $28.5 \pm 4.5$  years in Price and Campbell's participant group. Research conducted with able-bodied participants has found a direct impact of aging on the cardiorespiratory system. Maximal cardiac output, which is a major determinant of systemic oxygen transportation, decreases with age (Proctor, Beck, Shen, Eickhnoff, Halliwill & Joyner, 1998).

Training years may also be an important factor when looking at the variability in  $\text{VO}_{2\text{peak}}$  values. The current study had a large range for duration of sport participation, from 23 years to 1 month, which could account for the large dispersion in many of the values presented. Price and Campbell (1999) did not present the individual values for training years. Therefore a comparison is not possible. Another factor that may have

contributed to large variations in peak  $\text{VO}_2$  values within the sample is that the current study had two female participants, who had low values. The mean peak  $\text{VO}_2$  value for the male participants was  $20.2 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$ , which slightly increases the mean value of the entire sample but does not account for all of the differences seen with the current population.

For female athletes with a SCI, reports in the literature of aerobic data are very limited. Data available on four female athletes with T2 SCI showed the following:  $\text{HR}_{\text{peak}} 137.5 \pm 38.7 \text{ bpm}$ ,  $\text{VO}_{2\text{peak}} 0.73 \pm 0.22 \text{ l} \cdot \text{min}^{-1}$  and RER values of  $1.07 \pm 0.19$  (van der Woude et al., 2002). The two female participants in the current study had similar maximal values despite the range in SCI from T1 to T12-L1. Schmid et al. (1998) focused specifically on the physiological status of female athletes with an SCI. Their results in regards to maximal  $\text{VO}_2$  are much higher than the results from the current study. Their athletic population of thirteen participants had a mean maximal  $\text{VO}_2$  value of  $33.7 \pm 5.2 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$  whereas the sedentary females with an SCI had values closer to those found in the present study,  $18.3 \pm 3.3 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$ . Many of the athletes included in the athletic group of the Schmid et al. study had lower limb amputations and six of them had a SCI between T11 and L5. As discussed in the previous section, the level of SCI has an inverse relationship with maximal oxygen consumption. This low level of SCI or lack of any injury to the spinal cord normally results in more active muscle tissue which can lead to higher maximal oxygen uptake capacity.

Published research in the area of maximal testing with athletes with cerebral palsy (CP) is also very limited. Van der Woude et al. (2002) included 7 athletes with CP (6 male, 1 female). They reported average values of  $154 \pm 32 \text{ bpm}$  for  $\text{HR}_{\text{peak}}$ ,  $0.80 \pm$

0.44·min<sup>-1</sup> for VO<sub>2peak</sub> and a mean RER value of 0.98 ± 0.12 during a test of maximal aerobic capacity. The participant in the current study with CP had comparable maximal values.

#### **4.1.2 Participants' Body Composition**

The body composition data for wheelchair athletes is limited, and again, must be considered in the context of the individual nature and impact of the injury. Jones, Goulding and Gerrard (1998) assessed body composition using DXA in five paraplegic males, at least 1 year post injury (1 to 30 years post injury), and compared the results to those of 10 age matched able-bodied controls. In addition to a 16% reduction in lean tissue mass and a 12% reduction in bone mass, individuals in the SCI group had a 47% greater body fat percentage. The pooled results for percent body fat, FFM, and BMC of participants in the current study were comparable to the results reported by Jones et al. (1998). Similarities within the participant sample were also noted for time since injury. In the current study the range was 0.5 years to 28 years. However, when the results are separated by gender, the males in the current study had lower % BF and more FFM compared to the five males in the Jones et al. study. This difference is perhaps due to fitness level, as the five males were not reported as being athletes and there was no information provided regarding the participants' level of physical activity. Bulbulian, Johnson, Gruber and Darabos (1987) evaluated the body composition of twenty two male athletes with a SCI and compared them to 75 able-bodied controls. The percent body fat for the male athletes with a SCI were similar to the current study; they reported comparable values of 22.3 ± 8.8 % BF (Bulbulian et al., 1987).



One study which had a sample of male and female athletes with an SCI reported % BF results from DXA of  $25.1 \pm 7$  and mean BMI of 22.2 (Mojtahedi, Valentine, Arngrimsson, Wilund & Evan, 2008). Both values are lower than the body composition results from this study. It is important to note that the mean age from the Mojtahedi et al. (2008) study was 22.2 years, which may account for some of the differences. A limitation to their published results is that they did not separate their data by gender, which would provide more significance to their findings since published research with female data is very limited.

Changes in body composition which occur post SCI may be time dependent (Wells & Hooker, 1990; Garland et al., 1992). Garland et al. (1992) noted that bone loss occurred to the greatest extent during the first 3 to 6 months after the injury. The bone mineral content stabilizes at approximately 66% of the original mass at 12 to 16 months post SCI (Garland et al., 1992). The participants with a SCI (n=7) in the current study were  $15.6 \pm 9.3$  years post injury with a range of 0.5 to 28 years. One of the participants was only 6 months post injury at the time of the body composition exercise testing. Therefore his body composition data may have represented the initial changes that occur after injury. With his BMD value removed for analysis the mean value does not change:  $1.32 \text{ g} \cdot \text{cm}^2$  (n=6). The importance of the body composition data from the current study is not only for the characterization of the participants but also to contribute to the quantity of research in the area. With more research in this area new guidelines could perhaps be developed to look at body composition, specifically FFM, in related to resting energy and macronutrient requirements.

## 4.2 Fuel Use During Exercise

Fuel utilization during exercise is affected by intensity level, mode of exercise, fitness level and duration of exercise (Coggan, 1991). As exercise intensity rises, plasma glucose utilization increases due to an increase in muscle fibre recruitment in addition to an upsurge in glucose consumption by each active muscle fibre. In regards to mode of exercise, at the same relative intensity, the reliance on glucose is greater during exercise performed with a smaller muscle mass; for example arms versus legs (Ahlborg et al., 1986). In the current study the deltoid, biceps and triceps were the main movers, placing an increased dependency on CHO as the fuel source. This is supported by the elevated RER values noted in both trials. An individual's training status also plays a role in fuel utilization during exercise. As fitness level increases fat becomes a more dominant fuel source at higher intensities. This shift may be due to hormonal changes that occur in response to exercise in the trained individual versus the untrained (Coggan, 1991). The changes that occur are a decrease in glucagon and catecholamine concentration and an increase in insulin concentration which have a sparing effect on glycogen stores (Coggan, 1991).

The goal of CHO feeding during exercise is to provide a steady flow of exogenous glucose into the blood with minimal gastrointestinal distress with the intent of delaying the onset of fatigue (Coyle, 2004). The total CHO content of the beverage in the current study was 64 g, provided in four dosages of 200 ml. In relation to total body weight the dosage provided  $0.84 \pm 0.2 \text{ g CHO} \cdot \text{kg}^{-1}$ , exceeding the current ACSM, ADA, DC (2000) guidelines of  $0.7 \text{ g CHO} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$ . Maintenance of blood glucose may be more crucial for wheelchair athletes with a SCI because following injury there is a

reduction in type I muscle fibre and a shift to type IIb motor units in the paralysed limbs (Burnham, Martin, Stein, Bell, MacLean & Steadward, 1997). Type II muscle fibres have a higher capacity for glycogenolysis and glycolysis, while type I fibres have a greater capacity for fat oxidation (Holloszy, Kohrt, & Hansen, 1996).

In 2004 Spendiff and Campbell compared the effect of two different feeding regimes on a 20 minute performance trial following 60 minutes of exercise at 65%  $\text{VO}_{2\text{peak}}$  conducted on a roller system. One trial was two dosages of 324 ml and trial two was four dosages of 162 ml of a 7.6% CHO beverage. They did not find a significant performance difference between their two feeding regimes. They did however note an 11% improvement in the total distance covered in 20 minutes with the more frequent CHO feeding protocol (Spendiff & Campbell, 2004). This trend for performance improvements led to the feeding regime used in the current study. When providing the 8% CHO beverage every 15 minutes we were able to maximize not only their CHO intake but also the total volume of fluid consumed. Our study implemented strict dietary control between trials, a controlled pre-exercise meal and a longer performance trial. These changes in methodology may have resulted in no difference in performance between the CHO and placebo beverages.

The current hydration recommendation for able-bodied athletes during exercise is to consume between 150 to 350 ml of fluids every 15 to 20 minutes depending on individual tolerances (ADA, ACSM, DC, 2000). The feeding regime used in the current study for both trials provided the participants with the ideal hydration protocol. Total fluids consumed during the 60-minute exercise trial were 800 ml of either the 8% CHO beverage or the placebo provided every 15 minutes. Previous research conducted with

wheelchair athletes had not provided this volume of fluid. Spendiff and Campbell (2004) provided a total of 648 ml during the 60-minute exercise.

Prior to the exercise trial many of the participants were concerned about the volume of fluid to consume therefore a plan was in place in case they needed to stop the trial to void their bladder. None of the participants reported any negative symptoms of stomach discomfort or need to urinate when provided with this volume of fluid. It is encouraging to demonstrate that all of the participants, even those with impaired sweat function were able to tolerate this volume of fluid. The current study was able to demonstrate that the participants can follow the hydration guidelines in place for able-bodied athletes. Performance would not likely have been limited by hydration.

Although research with an able-bodied population has shown a performance benefit of fuel use during exercise (Below et al., 1995; McConell et al., 1996; Sugiura & Kobayashi, 1998), the results from the current study did not find any performance improvements ( $p=0.237$ ). Although six of the eight participants covered more distance during the second performance trial versus the first trial, when tested for statistical significance the order effect did not achieve significance ( $p>0.05$ ).

#### **4.3 Pre-Exercise Carbohydrate Feeding Regime**

A possible explanation for the lack in performance benefit when consuming the 8% CHO beverage could be due to the pre-exercise feeding protocol that was utilized. The rate of plasma glucose utilization during exercise can be influenced by an individual's pre-exercise nutrient intake (Coggan, 1991). Pre-exercise CHO feeding results in a change in fuel oxidation, shifting from free fatty-acid oxidation to an increase in glucose oxidation (Burke et al., 1998). It

is possible that the pre-exercise meal suggestions developed for each of the participants resulted in an adequate amount of fuel to complete the exercise and performance trial to the best of their physical ability based on their current training and fitness status. Ideal pre-exercise feeding, providing between 1 to 4 g CHO·kg<sup>-1</sup> body weight, was encouraged for all participants prior to both exercise trials. Each participant reported that they followed the dietary instructions prior to the exercise and performance trials. The goals of pre-exercise food consumption are to continue to fuel muscle glycogen stores if they have not fully recovered from a previous exercise session, to restore liver glycogen stores, especially following an overnight fast, ensure adequate hydration, prevent hunger, avoid gastrointestinal distress, and include foods that the individual feels confident with (Burke & Deakin, 2000). The pre-exercise meal might also explain the negligible use of fat as a fuel source during the exercise and performance trials as demonstrated by the high RER values.

Other studies have tried to identify whether performance gains observed with CHO ingestion during exercise are due to the pre-exercise meal or to the CHO beverage provided during the exercise trial. Chryssanthopoulos, Williams, Nowitz, Kotsiopoulou, & Vleck, (2002) studied the performance and metabolic response in nine male able-bodied athletes following the ingestion of a pre-exercise CHO meal plus either a CHO beverage or plain water during a run at 70% VO<sub>2peak</sub> to exhaustion. The performance parameter that was assessed was the exercise time to exhaustion. Similar to the current study, the pre-exercise meal was consumed 3 hours prior to exercise and contained 2.5 g CHO·kg<sup>-1</sup> body weight. For the trial with the CHO beverage during exercise, the beverage was a 6.9 % CHO beverage and was provided every 20 minutes at a dosage of 2 ml·kg<sup>-1</sup> body weight, which is approximately 146 ml. The participants had a relatively high fitness level of 63.5 ± 2.3 ml·kg<sup>-1</sup>·min<sup>-1</sup> VO<sub>2max</sub>, and maximal heart rate of 186 ±

4 bpm. There were no significant differences in oxygen uptake, heart rate, blood lactate and RPE values; findings which are similar to the current study. There was a performance benefit noted between the groups, the CHO meal pre-exercise plus the CHO beverage during the trial resulted in an increased time to exhaustion. It is important to note that the RER values during the first collection period were also elevated (0.96 in the meal plus CHO beverage and 0.95 in the meal plus water trial) (Chryssanthopoulos, et al., 2002). The authors also noted that the pre-exercise CHO meal led to the suppression of FFA mobilization and glycerol concentrations in the blood, producing a greater reliance on CHO as the dominant fuel source. Insulin levels were also elevated following the CHO meal pre-exercise, which has a direct impact on fatty acid utilization (Chryssanthopoulos, et al., 2002). An interesting point that was noted by Chryssanthopoulos, et al. (2002) was that the pre-exercise meal might have led to an additional energy source at the start of the exercise trial with undigested CHO still present in the gastrointestinal tract, which may also contribute some CHO for muscle metabolism.

The most recent study published by Spendiff and Campbell (2005) assessed the impact of pre-exercise CHO feeding. They provided eight male athletes with an SCI with either a 4 % or 11 % CHO beverage 20 minutes prior to the exercise and performance trial. The beverage contained either 24 g or 72 g of dextrose monohydrate in a 600 ml solution. No additional CHO source or fluid was provided during the exercise and performance trial. The concentration of CHO provided pre-exercise did not affect the performance measures of power output or distance covered (Spendiff & Campbell, 2005). The CHO content of the pre-exercise beverage did however affect the free fatty acid (FFA) concentration. The 4% CHO beverage resulted in significantly higher levels at the completion of the 1 hour exercise trial. While the current study did not measure FFA concentration it was apparent during the exercise and performance trials

that the dominant fuel source was glucose, as supported by the elevated RER values. The pre-exercise CHO feeding regime used in the current study may have had a similar effect on fatty acid oxidation as indicated by RER values at the end of the performance trial. The RER values were significantly lower during the last 10 minutes (20-30 min) of the placebo trial versus the CHO beverage trial.

#### **4.4 Respiratory Exchange Ratio**

Respiratory exchange ratio was calculated during the exercise and performance trials as the ratio between the volume of CO<sub>2</sub> released and the volume of O<sub>2</sub> consumed. This method does have some limitations. It assumes that the body's oxygen content remains constant and that the CO<sub>2</sub> exchange at the lungs is proportional to its release from the cells (Wilmore, Costill, & Kenny, 2008). During the 60-minute exercise trial there was a significant interaction and post hoc tests revealed significantly higher RER values for the final 5 minutes of the 1 hour exercise component ( $p < 0.05$ ). From the first collection period during the 60-minute exercise trial the RER values were indicative of almost complete utilization of glucose, for both beverage trials. These data are in contrast to that of Spendiff and Campbell (2004) who reported lower RER values ( $0.91 \pm 0.05$ ) during exercise at  $60 \pm 3\%$  VO<sub>2peak</sub>, for first 20 minutes of the 4 x 162 ml feeding regime trial. Reasons for this difference could have been due to the pre-exercise feeding regimen as suggested by Chrysanthopoulos, et al. (2002), who reported RER values of 0.96 and 0.95 three hours after the pre-exercise meal in able-bodied male athletes. The current study provided instructions on the ideal pre-exercise meal, providing example food portions of high CHO choices. Spendiff and Campbell (2004)

instructed consumption of the participant's normal food intake and a three hour fast.

They did not encourage any specific CHO content for the meal. It is well recognized that as more CHO is utilized RER values get closer to 1.0, indicating increased demands on blood glucose and muscle glycogen stores and increased carbohydrate oxidation (Wilmore, Costill, & Kenny, 2008).

In the present study, RER values during the final 10 minutes of the performance trial (20-25 & 25-30 min) were significantly higher during the CHO beverage trial than the placebo trial. The RER results from the current study are in contrast to the findings of Spendiff and Campbell (2004). The RER results presented for the more frequent feeding regime were much lower during the performance trial. The average RER values for the performance trial were  $0.94 \pm 0.03$  for the 4 x 162ml feeding regime (Spendiff & Campbell, 2004). With a comparison made between our CHO beverage trial and Spendiff and Campbell's (2004) more frequent feeding regime, the RER values indicate that the methodology used in the current study resulted in a greater dependency on CHO as the dominant fuel source during the performance trial.

In the present study the RER values for both trials were high beginning with the first collection period and remained elevated throughout the exercise and performance trial. When the RER values were assessed by injury level, similar trends were noted. For the three male participants classified as having paraplegia (T3, T4, L1), the RER response followed the same relative curve, with high values noted in both trials beginning with the first collection period. The CHO beverage trial resulted in RER values above 1.0 for the entire 30-minute performance trial. Values at the end of the performance trial for the CHO beverage and placebo trial were above 1.0, indicating that



CHO was the dominant fuel source. With the two male participants with quadriplegia (C6, C5-6) the RER values were more erratic. The participant with SCI at C5-6 had higher RER values during the placebo trial. Values at the completion of the 30-min performance trial were 1.03 for the placebo trial and 0.99 for the CHO beverage trial. Reasons for this cannot be explained by relative exercise intensity as both trials were conducted at very similar percentages of  $\text{VO}_{2\text{peak}}$ . Another individual who demonstrated very unique RER values was the participant with CP. His RER values were very erratic; the placebo trial resulted in higher RER values for most of the performance trial. The CHO beverage trial RER values were erratic and did not follow a similar pattern in comparison to the other participants. For the female participants (T12-L1, T1), the CHO beverage trial resulted in higher RER values for the 60-minute exercise and performance trial. This is important to note especially since both participants conducted the CHO beverage trial during the luteal phase of their menstrual cycles, which has been shown to result in lower RER values (Hackney, 1999). They completed the placebo trial during the follicular phase, in which the RER values were consistently lower.

Determining the cause for such variability in RER values for each of these participants would be very challenging as no other published study has presented individual data. Speculations could be made regarding individual fitness level, level of injury, or active muscle mass involved in the exercise. As noted in the previous section, the pre-exercise feeding regime might have also played an important role. Having a relatively high CHO meal three hours prior to both exercise and performance trials may have lead to minimal fat oxidation. The findings for the paraplegic participants from this study are supported by previous research with an SCI population that has shown

elevated RER values during exercise (Astorino & Harness, 2009; Knechtle et al., 2004). Obviously many unique factors are involved in fuel metabolism during exercise.

Campbell, Williams, & Lakomy (2004) reported a significant decrease in RER during a 90 minute exercise trial without a CHO fuel source. Twenty athletes with a variety of spinal cord injuries participated in their research study. The RER values decreased significantly as the exercise test progressed ( $p < 0.05$ ). Respiratory exchange ratio of 0.91 for the T3 athletes and 0.92 for the T4 athletes were noted at the start of the exercise and dropped to 0.82 for the T3 athletes and 0.80 for the T4 athletes at the completion of the 90-minute exercise (Campbell, Williams, & Lakomy, 2004). The decrease in RER as the exercise regime progressed indicates a switch to lipid metabolism. Values seen with able-bodied individuals at rest are usually in the range of 0.78 to 0.80 (Wilmore, et al., 2008). As noted in the current study, the average RER values during the first collection period (0-5 min) were  $0.99 \pm 0.04$  for both the placebo trial and CHO beverage trial, indicating very limited use of fat as a fuel source.

Throughout the placebo trial the RER values dropped by a small amount. However individual calculations of fat oxidation still revealed negative values, suggesting negligible fat oxidation. The cause for this dependence on carbohydrate as the primary fuel source even at moderate intensities of 57 %  $\text{VO}_{2\text{peak}}$  may be due to the pre-exercise meal being high in total grams of CHO in conjunction with the arm specific mode of activity.

Providing instructions on ideal pre-exercise feeding may have resulted in an increase in glucose availability during both exercise trials. Pre-exercise CHO feeding has been shown to increase insulin levels, decrease glucagon levels which may suppress

fat metabolism and maintain higher rates of CHO oxidation later into the exercise trial (Coyle, 1999). The transport of fatty acids through the mitochondrial membrane can limit fat oxidation during exercise and this process is sensitive to CHO metabolism, indicating that during exercise fat oxidation in the skeletal muscle is largely regulated by CHO metabolism. Conditions which have shown a shift away from fat oxidation are pre-exercise CHO intake and increased exercise intensity. There seems to be a preference for CHO when both CHO and fat are available to the muscle and this may be mediated by active inhibition of fat oxidation through a process that involves the transport of fatty acids into the mitochondria. Sidossis (1998) found that glucose directly determines the rate of fat oxidation by controlling fatty acid transport into the mitochondria even at moderate intensities of 30 to 65 %  $\text{VO}_{2\text{max}}$ . At intensities above 65 %  $\text{VO}_{2\text{max}}$  the relative contribution of glucose from plasma and the breakdown of muscle glycogen increase and total fat contribution decreases (Sidossis, 1998). Therefore an ideal CHO pre-exercise meal actively and directly inhibits the oxidation of fatty acids at the skeletal muscle. The participant's ability to oxidize fatty acids even at moderate intensities (57 %  $\text{VO}_{2\text{peak}}$ ) might have been limited by their level of fitness, especially their endurance fitness. Many of the participants were from team sports which would not necessarily mean that they train their aerobic system to the same extent as endurance athletes. Untrained able-body athletes have lower fat oxidation rates during moderate intensity endurance training versus endurance-trained athletes (Coyle, 1999).

Another explanation for the complete dependency on CHO as the dominant fuel source during exercise for both trials may be due to the mode of exercise. Ahlborg, Wahren and Felig (1986) studied the metabolic impact of either leg or arm exercise with

able-bodied participants. Their study included twelve male participants, six of who performed the arm exercise trial while the other half completed the leg trial. The exercise trial was two hours in length at low intensity of 30 %  $\text{VO}_{2\text{peak}}$ . The arm exercise trial led to a 25 to 40 % increase in heart rate, increased arterial concentrations of lactate, catecholamines, FFA and a significant increase in RER values. Arm exercise resulted in a greater utilization of glucose by the exercising muscle tissue as well as an increase in hepatic gluconeogenesis from lactate and glycerol. The authors proposed that the difference in fuel utilization between the leg and arm exercise was due to increased glucose oxidation increased in arm exercise due to smaller muscle mass activation (Ahlborg et al., 1986). Therefore a greater intensity of work done by the individual muscle groups was required to maintain the same intensity. They also noted the differences in muscle fibre composition and enzyme activity in the arm muscles versus the legs (Ahlborg et al., 1986). Due to normal daily activity, the leg muscles have a greater content of oxidative enzymes. Obviously a major difference between the able-bodied participants in the Ahlborg et al. (1986) study and the current research is that individuals with a SCI might adapt and become more efficient with arm exercise.

#### **4.5 Carbohydrate Oxidation During Exercise**

Carbohydrate oxidation was calculated using the equations of Jeukendrup & Wallis, (2005), which considers protein oxidation as negligible. This assumption is appropriate for the current study since protein is normally only oxidized when individuals are exercising in a fasted state, performing prolonged exercise or are under metabolic stress (Rodgers, 1998). In a study conducted by Campbell et al. (2004), they

did note that amino acid oxidation may have occurred during the 90-minute exercise trial. Their results indicated that both ammonia and urea concentrations were elevated for all paraplegic racing classes at the end of the exercise. The difference in methodology may explain why the current study is making the assumption of negligible protein oxidation. Campbell et al. instructed the participants to arrive in a fasted state and did not provide instructions regarding their pre-exercise feeding regime. The current study provided detailed instructions to ensure that the CHO content of the meal would be optimal. For both exercise trials the participants were not in a fasted state as they had been instructed to consume a pre-exercise meal 3 hours prior to the trial.

During the 60-minute exercise trial there was no significant main effect of time for CHO oxidation ( $p=0.087$ ). For the 30-minute performance trial a significant interaction was noted. Post hoc analysis revealed that the CHO beverage resulted in higher CHO oxidation rates during the final 5 minutes of the performance trial. These findings are consistent with our primary hypothesis that the 8 % CHO beverage trial would result in higher oxidation of CHO versus the placebo beverage trial. Although provision of the CHO beverage resulted in an increased rate of oxidation this factor did not impact the participant's performance or rating of perceived exertion. Performance may have been improved if the participants were to have completed the exercise trial in a fasted state as discussed in the previous sections, placing a greater dependency on exogenous CHO sources. Limited information is available on CHO oxidation during exercise for athletes with a physical disability. Previous published research with this population has not provided detailed information on CHO oxidation values for comparison.

#### **4.6 Impact of CHO Feeding on Blood Glucose Values**

The goal of CHO feeding during exercise is to provide a steady flow of exogenous glucose into the blood with minimal gastrointestinal distress (Coyle, 2004). During the CHO beverage trial there were no anecdotal reports of gastrointestinal upset or intolerances of the volume of fluid provided. For the blood glucose results there was a significant beverage by time interaction, with each beverage affecting the blood glucose values differently over time. The 8 % CHO beverage trial resulted in higher blood glucose values during the 60-minute exercise trial and at the completion of the 30-minute performance trial compared to the placebo beverage trial. Similar results were reported by Spendiff and Campbell (2004) who demonstrated that the more frequent feeding regime, 4 x 162 ml of 7.6 % CHO beverage resulted in more steady blood glucose levels versus the 2 x 324 ml regime. The individual blood glucose responses to both trials can be found in Appendix IX. A similar trend in blood glucose values was found for five of the male participants (C6, C5-6, T3, T4, L1). For all five, the CHO beverage trial resulted in higher blood glucose values during the exercise, performance trial and into the recovery period. The same pattern was not shown however with the two female participants (T12-L1, T1). Their blood glucose responses were observed to be higher during the CHO beverage trial for the 40-min, 60-min and post collection periods, but during the recovery phase the placebo trial resulted in higher values. A similar response was noted with the participant with CP. Reasons for this variability in blood glucose response is not known. It may have been caused by the breakdown of amino acids via gluconeogenesis in order to supply adequate glucose for the muscle and nervous systems. Both of the female participants conducted the placebo trial during the

follicular phase of their menstrual cycles, but previous research has shown that CHO consumption during exercise at varying times during the menstrual cycle does not impact blood glucose response (Bailey et al., 2000).

The results from our study demonstrate that even though blood glucose was maintained with the 8 % CHO beverage, it was not enough to lead to a performance gain. The performance benefit of the enhanced levels of glucose may have been noted if the participants continued to exercise for a longer period of time, placing a greater emphasis on exogenous CHO. Carbohydrate consumption during exercise over 2 hours has been shown to delay the onset of fatigue and prevent the development of hypoglycaemia due in part to the sparing of liver glycogen stores (Coyle, 2004).

Since this study is the first to date to conduct a 30-minute performance trial immediately after the 60-minute exercise trial, it was a concern that some of the participants would not be able to complete the full performance trial. Only one participant was not able to complete the full trial (completed 22:33.00 of the 30-minute performance trial). Therefore for the second exercise and performance trial their time was limited to 22:33.00 so that comparisons could be made between trials based on total distance covered. One anecdotal report from a participant was that at the completion of the 30-minute performance trial with the placebo beverage they experienced full body fatigue, more so than during the CHO beverage trial. Since blood glucose levels were more stable during the CHO beverage trial, this help to explain the different in full body fatigue. One of the major benefits to CHO feeding during exercise is that maintaining blood glucose levels encourages ongoing training leading to enhanced endurance capacity. The participants would not be forced to stop exercising due to the depletion of

muscle glycogen stores or the development of hypoglycaemia (Holloszy, Kohrt, & Hansen, 1996). The overall health benefits of improved endurance capacity, fitness and perhaps a change in body composition would definitely lead to the recommendation of CHO consumption during prolonged training sessions.

#### **4.7 Impact of Gender on Fuel Utilization**

Numerous studies have demonstrated that women have a lower RER during exercise when compared to men, indicating a greater reliance on fat oxidation (Devries et al., 2006; Braun et al., 2005). The reduced oxidation of CHO during exercise could be due to a decreased utilization of muscle glycogen, lower utilization of blood glucose or both (Horton et al., 2006). Since previous research has found that the hormonal fluctuations that occur during the menstrual cycle may impact glycogen utilization during exercise, both female participants were asked about their menstrual cycle schedule in relation to the testing dates. Hackney (1999) found that muscle glycogen utilization was lower during the luteal phase when oestrogen was the highest and that a significant negative relationship existed between the oestrogen levels and the amount of glycogen utilization. They noted that RER values were significantly lower during the luteal phase versus the follicular phase, suggesting enhanced lipid utilization during exercise (Hackney, 1999). Under conditions similar to the current study, Bailey et al. (2000) studied the impact of a CHO beverage consumed during exercise to see if providing a fuel source during exercise would negate the impact of the menstrual cycle on fuel utilization. Their research design involved four exercise trials, two during the luteal phase and two during the follicular phase. During both phases the nine female



participants were provided with either a 6 % CHO beverage or placebo. The participants were told to cycle to exhaustion. Their results indicated that the time to exhaustion was increased with the CHO beverage, but there was no difference between the luteal and follicular phase. There was also no difference between phases for FFA, plasma glucose or insulin levels. Although our study did not find the performance gains, one similarity is that Bailey et al. (2000) did not find an impact of the 6 % CHO beverage on the participants' RPE values. For the two female participants included in this study, menstrual cycle was documented but was not controlled.

Due to three female participants not completing all aspects of the research study, both females that did complete the exercise trials received the CHO beverage during the first exercise trial and the placebo beverage during the second trial. Participant 3 conducted her first exercise trial with the CHO beverage on day 28 of her menstrual cycle and her second trial with the placebo beverage on day 7 of her menstrual cycle. Participant 8 conducted her first exercise trial with the CHO beverage on day 25 of her menstrual cycle and her second exercise trial with the placebo beverage on day 4 of her menstrual cycle. For both female participants the CHO beverage did not enhance performance.

#### **4.8 Impact of CHO Feeding on Blood Lactate Values**

There was a significant main effect of time ( $p > 0.05$ ) for lactate, indicating that when the pooled means from both the CHO trial and placebo trial were combined there was a significant difference across time points. The blood lactate values increased over time as expected. There was no effect of the CHO beverage on the lactate values during

the 60-minute exercise trial or any of the post-performance values ( $p=0.082$ ). The lactate values for the three males with paraplegia were quite erratic in pattern. All three had elevated values for both the CHO beverage and placebo post-performance trial. During the recovery phase each participant's values followed a similar decreasing pattern. For the two female participants, the lactate responses were quite unique. Both had elevated values after the performance trial, but the spikes in values were different between the two trials. The participant with an SCI at T1 had a spike in blood lactate values at 2-min post during the placebo trial ( $19.7 \text{ mmol.l}^{-1}$ ) and a spike at 5-min post with the CHO beverage trial ( $15.4 \text{ mmol.l}^{-1}$ ). The increase in blood lactate during the placebo trial does correspond with an increase in blood glucose values at 2-min post performance trial. Deschenes, Hillard, Wilson, Dubina, and Eason (2006) noted that blood lactate post exercise and during the recovery phase (5-min and 15-min post) is higher in male participants versus females. This pattern was not evident in the current study. For the two males with quadriplegia the blood lactate values followed a similar pattern. The values were higher post exercise and into the recovery period during the CHO beverage trial. The participant with CP had a different blood lactate response. The values spiked at 2-min post but the placebo trial resulted in higher values. The lactate values at 2-min post followed the same pattern as the blood glucose response during the placebo trial. For all of the participants the blood lactate values at the end of the recovery period (10-min post) were still elevated, which could be a reflection of their fitness level and the muscle fibre type involved in the exercise. Blood lactate would accumulate, even during moderate intensity exercise, due to active muscle mass not having the oxidative capacity to oxidize lactate. Therefore accumulation would exceed removal rate.

When comparing the group mean values from the current study, research conducted with able-bodied participants has shown similar results for blood lactate values during exercise. Dumke, McBride, Niemen, Gowin, Utter and McAnulty (2007), found that providing either a 6 % CHO beverage or placebo during a 2.5 hour cycling protocol did not impact blood lactate levels. Murray et al. (1989) studied the effect of ingesting fluids of varying CHO content during a 1.25 hour intermittent cycling trial in a warm environment. Both male and female participants were recruited and 12 completed the study. The exercise trials were also conducted at 65 %  $\text{VO}_{2\text{peak}}$ , and each participant completed the trials on four separate occasions. The treatment beverages were a water placebo, 6 % sucrose, 8 % sucrose, and 10 % sucrose. With all four trials blood lactate values increased significantly over time but there was no difference between treatment trials (Murray et al., 1989). The CHO beverages resulted in higher blood glucose values and RER values during the final 20 minutes of the performance trial, which is similar to the findings of the current research study.

#### **4.9 Oxygen Uptake and Heart Rate Values**

Analysis of the physiological response to the 60 minute exercise trial indicated that the participants were exercising at  $57.4 \pm 6.8$  %  $\text{VO}_{2\text{peak}}$  and  $57.1 \pm 6.5$  %  $\text{VO}_{2\text{peak}}$  during the CHO beverage trial and placebo trials respectively. For the 30-minute performance trial, there was no significant difference in the percent  $\text{VO}_{2\text{peak}}$  values. There was a significant effect of time for both the 60-minute exercise trial and 30-minute performance trial for  $\text{VO}_2$  ( $\text{l} \cdot \text{min}^{-1}$ ) although there was no significant difference between beverage trials. The increase in  $\text{VO}_2$  was expected as previous research

conducted with wheelchair athletes has shown similar results (Spendiff & Campbell, 2004, 2005). Heart rate did not change over time during the 60-minute exercise trial, indicating that the participants were able to maintain a steady state of exercise intensity over the 60 minutes prior to the start of the performance trial. As expected, heart rate increased during the performance trial ( $p=0.009$ ). Heart rate during the performance trial was not affected by the nature (CHO or placebo) of the beverage consumed ( $p>0.05$ ). Spendiff and Campbell (2004) found that  $\text{VO}_2$  ( $\text{l}\cdot\text{min}^{-1}$ ) and heart rate increased during the exercise and performance trials but there was no significant main effect of the beverage feeding regime, which is consistent with the current study.

#### **4.10 Rating of Perceived Exertion**

Research with able-bodied athletes has shown that RPE is significantly lower following the ingestion of CHO during exercise compared to a placebo beverage (Backhouse et al., 2005). Utter et al. (2007) studied the impact of CHO feeding during intermittent exercise on RPE with 12 male cyclists. The exercise trial included 2 hours at 73 %  $\text{VO}_{2\text{peak}}$  with 3-minute rest intervals every 10 minutes. The participants were provided with a 6 % CHO beverage or placebo beverage pre-exercise and during the trial. During the last minute of each 10-minute bout of exercise the participants rated their overall body RPE. The RPE patterns were significantly different between the CHO and placebo trials. The data indicated that CHO supplementation during intermittent exercise attenuated perceived exertion (Utter et al., 2007). Our results are not consistent with these findings.

There have been some published research studies that support our findings. Brisswalter, et al. (2000) examined the effect of a 5.5 % CHO or placebo beverage on the energy cost of

running in ten male triathletes. Providing either the 5.5 % CHO beverage or placebo in 140 ml dosages every 20 minutes during the 2-hour running trial did not affect the energy cost of running or the RPE. The RPE increased over time but did not differ between trials, similar to the present study. One comparison that cannot be made is whether or not a pre-exercise meal led to this lack of difference in RPE between trials, as Brisswalter et al. (2000) did not comment on the pre-exercise meal. In the present study the pre-exercise meal was controlled and this meal may have provided the participants with adequate fuel to complete the exercise and performance trial on both occasions to the best of their ability with no significant impact on their perception of work effort or fatigue.

It is of note that one participant did respond differently to the two beverages and reported the feeling of overheating during the placebo trial at minute 12 into the 30-minute performance trial. The participant's body temperature was not measured during the exercise trials, but it was apparent that this participant had to decrease their intensity during the performance trial due to their discomfort. Future research should also monitor body temperature during exercise to identify if nutrient or electrolyte beverage composition affects temperature regulation in individuals with impaired sweating.

#### **4.11 The Participants' Dietary Intake Patterns**

In order to make individual dietary recommendations, information on total energy requirements is necessary. The published data regarding energy needs of individuals with varying levels of ability includes participants with amputations, varying levels of paralysis, spinal cord injuries, and cerebral palsy. To state that this information can be

applied specifically to athletes with paraplegia or quadriplegia would not be appropriate. Research has been conducted with sedentary individuals with SCI in order to determine the effect of the level of injury on resting energy needs and thermic effect of food (TEF). Monroe et al. (1998) studied 10 male participants with varying levels of spinal cord injuries. The participants were classified as sedentary to moderately active; therefore they were not an athletic population. There was a significant reduction in daily energy expenditure in the SCI participants versus the able-bodied controls. After adjustments were made to account for the lower FFM values in the SCI group, the 24 hour energy expenditure was on average  $180 \text{ kcal} \cdot \text{d}^{-1}$  lower in this group compared to the able-body controls ( $p < 0.01$ ). They reported 24-hour energy requirements of  $1,869 \pm 73 \text{ kcal} \cdot \text{d}^{-1}$  for the ten male SCI participants. A difference was found between the two groups for spontaneous physical activity, with the SCI group reporting lower energy values. They also found a significant difference between groups for the TEF. Thermic effect of food accounted for 12.1 % of total energy intake for the SCI participants and 15.3 % for the able-bodied controls. Abel et al. (2003) measured resting energy requirements for 27 athletes with a variety of physical abilities (SCI, spina bifida, amputations, post-polio syndrome), and found mean basal metabolic rates to be  $65.4 \pm 14.1 \text{ kcal} \cdot \text{hr}^{-1}$  for the hand bike athletes and  $60.3 \pm 9.1 \text{ kcal} \cdot \text{hr}^{-1}$  for the wheelchair racing athletes. These values would result in resting daily requirements of 1,488 to 1,560  $\text{kcal} \cdot \text{d}^{-1}$  plus additional energy needs for physical activity. Comparing these values to our current population would indicate that energy needs are being met, with  $2,438 \pm 528 \text{ kcal} \cdot \text{d}^{-1}$ , but since each participant has a unique level of physical ability making these types of comparisons might not be appropriate.

Level of injury will determine the muscle groups being used on a daily basis which will impact energy needs, but the energy cost of daily living (transfers, mobility, etc.) will be much greater than non-SCI individuals (Cox et al., 1985). Cox et al. studied the energy requirements of 22 sedentary individuals with a SCI that were currently undergoing rehabilitation in a hospital setting using indirect calorimetry. The results indicated that the individuals with quadriplegia needed  $22.7 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$  and individuals with paraplegia required  $27.9 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ . Dietary estimates made from a 24-hour recall indicated that energy intake was exceeding caloric requirements with individuals consuming approximately  $1,774 \text{ kcal} \cdot \text{d}^{-1}$  ( $27.4 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ ). The dietary estimates were also supported by the fact that the participants were gaining weight, indicating that a positive energy balance was being achieved. Detailed information regarding the dietary composition was not provided. The mean energy intake from the current study was  $31.6 \pm 7.1 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ , which exceeded the values reported by Cox et al. (1985). Making a comparison to the findings by Cox et al. may not be appropriate however since their population was sedentary; therefore increased activity levels could account for the increased energy needs of the participants in the current study. Information regarding trends in body weight was not collected, therefore it is not known if the participants were exceeding their energy needs. Only two of the participants in the present study were below the caloric needs identified by Cox et al.

Published data describing the dietary patterns of wheelchair athletes is, to the best of our knowledge, unavailable. Nutritional information was collected using a modified 3-day food record. The food records were used primarily to control for dietary intake between the two exercise and performance trials. Since the existing nutritional literature

is lacking specific energy and macronutrient recommendations for wheelchair athletes, able-bodied guidelines for athletes and active adults were utilized for comparison. The current ADA, ACSM and DC (2000) recommendations were viewed as the top end of the range for energy and macronutrient intake. The low end of the range was the acceptable macronutrient distribution range (AMDR) values and the RDA and AI values (IOM, 2005). The AMDR values are a percentage of total calories consumed (% kcal). The AMDR values are 45 to 65% kcal for CHO, 10 to 35% kcal for protein and 20 to 35% kcal for fat (IOM, 2005). It has been stated that “any macronutrient needs of an athlete should also fit within these AMDR ranges” (Zello, 2006, p.75). Only 25% of the participants met the daily caloric recommendations for active adults (active = 37 to 41 kcal·kg<sup>-1</sup>·d<sup>-1</sup>; SCI = 31.59 ± 7.10 kcal·kg<sup>-1</sup>·d<sup>-1</sup>). An important consideration with estimates of energy requirements is that the values are only estimates. In regards to energy intake, the participants were not asked about their body weight history. This information could have been used to assess if energy intake patterns are maintaining body weight, causing a gain in weight or a loss. Knowing their body weight history would have provided additional information concerning whether they were achieving an energy balance.

Carbohydrate recommendations of 6 to 10 g·kg<sup>-1</sup> body weight·d<sup>-1</sup> were not met by any of the wheelchair athletes. This recommendation is to maintain blood glucose levels during exercise and to replace muscle glycogen stores (ADA, ACSM, & DC, 2000). The mean intake of CHO was 4.02 ± 0.75 g·kg<sup>-1</sup> body weight·d<sup>-1</sup>. Seven of the eight participants were within AMDR and were all meeting the RDA for CHO (130 g·d<sup>-1</sup>). Since the participants in this study have less active muscle mass in comparison to able-



bodied athlete and active adult guidelines may not be suitable. Therefore the participants may have been consuming enough CHO on a daily basis to result in adequate muscle glycogen stores. This is supported by the blood glucose and RER values found in both exercise and performance trials. The impact on RER values could have resulted from the pre-exercise meal alone or from the dietary habits leading into the exercise trials. This complete dependency is not normally seen when participants consume a low CHO diet, RER indicates a higher utilization of FFA when muscle glycogen levels are low (Coggan, 1991).

Dietary protein needs are dependent on the type of sport involvement. It is recommended that strength athletes consume 1.6 to 1.7 g·kg<sup>-1</sup> body weight·d<sup>-1</sup>, and endurance athletes 1.2 to 1.4 g·kg<sup>-1</sup> body weight·d<sup>-1</sup> (ADA, ACSM, DC, 2000; Burke & Deakin, 2000). The participants from the current study were involved in neither strength nor endurance specific events. When compared to the overall recommendation of 1.2 to 1.7 g·kg<sup>-1</sup> body weight·d<sup>-1</sup> 63% of the participants were meeting this recommendation. In comparison to the RDA value for protein (0.8 g·kg<sup>-1</sup> body weight·d<sup>-1</sup>) only one participant was below the recommendation. All of the participants were within the AMDR for this macronutrient. Average caloric intake from fat was 31 ± 5.8 % which exceeded current recommendation of 20-25 % total energy for the athletic population (ADA, ACSM, DC, 2000). In relation to the AMDR, two of the participants were above the range (>35% total kcal). When total fat intake exceeds the AMDR; total CHO for optimal muscle glycogen levels may be compromised. When a high fat diet is consumed on a daily basis it may limit an athlete's ability to train effectively (Helge, 2000).

Total daily fluid intake was below gender specific adequate intake values of 2,700 ml for females and 3,700 ml for males. The mean value for total fluid intake was  $2403 \pm 650 \text{ ml} \cdot \text{d}^{-1}$  (IOM, 2004). Since the AI for fluid also includes fluid sources from food the actual fluid intake would be slightly higher. Fluid from food usually accounts for 20 % of fluid intake and 80 % comes from liquids consumed. The AI for fluid also indicates that active individuals may require more fluid on a daily basis.

#### **4.12 Research Limitations**

Sample size is an important limitation of this study. Power calculations had been completed prior to the start of data collection, and it was determined that 15 participants would be needed in order to achieve statistical power. The initial recruitment met the sample size requirement, but due to scheduling issues, injuries not related to the study and travel complications, only eight participants completed the full research study. More participants may have provided more insight into the impact of the CHO ingestion on fuel utilization and RPE. Other limitations with this study were the broad range of SCI and physical abilities (CP). These factors may have contributed to the large variability observed in many of the dependent variables measured.

The differing electrolyte content of the two beverages may also have been a limiting factor as this may have impacted hydration status during exercise. The electrolyte composition for the 800 ml of 8% CHO beverage was 448 mg sodium, and 139 mg potassium (Orange, Gatorade, Pepsico, Inc.). The placebo beverage contained 160 mg sodium and 48 mg potassium per 800 ml (Orange, Nestea Acitv, Splenda© brand). The main focus with the beverage composition was to find a placebo control

beverage that tasted similar to the CHO beverage. Since many of the participants have used Gatorade products before, we needed the placebo to be similar in taste and color. The placebo beverage was a great match for both taste and color but it did contain electrolytes.

The limitations with using food records to determine an individual's dietary intake include: underreporting, measurement effect, and error associated with portion size estimation (Block & Hartman, 1989). While efforts had been put in place to minimize these limitations, they must still be recognized. More space was provided for the meals and snack recording and individual instructions were provided to each participant by a registered dietitian detailing how to correctly complete the food records. Even with the adjustments and education provided, under or over reporting could have occurred. Underreporting is the main limitation with self reporting food records. Therefore the actual dietary intake of the participants may have been higher than the results stated in this study. This would have had an impact on the 3-day food record results posted in addition to the energy available for each exercise trial in the form of muscle glycogen. Since muscle glycogen was not measured, the 3-day food record was the control for stored fuel sources leading into each trial. A large variation in CHO food intake would have resulted in different muscle glycogen stores and therefore varying the starting endogenous CHO stores. There was no measure of compliance incorporated in this study such as laboratory measures to assess macronutrient intake or hydration status.

Another possible research limitation is the order effect. When the statistical analysis was conducted the order effect was not significant ( $p=0.096$ ). Six of the participants performed better during the second exercise and performance trial,

independent of the beverage provided. Only two participants covered a greater distance during the first exercise and performance trial versus the second trial. Both of these participants had the placebo during the first exercise and performance trial. Methodology used in this study had tried to avoid the possible order effect by conducting the  $\text{VO}_{2\text{peak}}$  testing on the same exercise equipment in order to act as a familiarization trial. Perhaps a full exercise and performance trial held for the full 90 minutes would have decreased the effect of order on performance measures.

## CHAPTER 5

### 5. SUMMARY & CONCLUSIONS

#### 5.1 Summary

This study investigated the effect of ingesting an 8 % carbohydrate beverage during a moderate intensity exercise bout followed immediately by a 30-minute performance trial on performance outcomes, fuel utilization and blood glucose levels of wheelchair athletes. Under random, double blind conditions seven athletes with a SCI and one athlete with CP completed two exercise and performance trials. During the 60-minute exercise trial the participants were given four 200 ml dosages of an 8 % CHO beverage or a taste-matched placebo beverage. It was hypothesized that consumption of the CHO beverage would result in improved performance, maintain blood glucose values and lower ratings of perceived exertion. The secondary purpose was to analyse the dietary intake of the eight participants and determine if they were meeting the sport nutrition guidelines for able-bodied athletes and active adults according to the American Dietetic Association (ADA), American College of Sports Medicine (ACSM) and Dietitians of Canada (DC) joint position paper.

The results of the study failed to demonstrate any significant difference between beverages for total distance (km), average speed ( $\text{km}\cdot\text{h}^{-1}$ ) or maximum speed achieved ( $\text{km}\cdot\text{h}^{-1}$ ) during the performance trial. Only two of the eight participants covered more distance during the CHO beverage trial versus the placebo trial. Consumption of the CHO beverage did however result in higher blood glucose levels and greater CHO oxidation rates versus the placebo beverage. The CHO beverage also resulted in higher

RER values during the exercise and performance trial. The ratings of perceived exertion were not affected by consumption of the CHO beverage. When comparing the participant's dietary intakes to the current able-bodied athlete's recommendations, they were not consuming enough total calories, total CHO and were exceeding the range for fat intake. The results from the 3-day foods records indicated that the participants were not meeting the current dietary recommendations for able-bodied athletes. Only 25 % of the participants met the daily caloric requirements for able-bodied athletes.

Carbohydrate requirements of 6 to 10 g·kg<sup>-1</sup> body weight·d<sup>-1</sup> were not met by any of the participants. Only 63 % of the participants were meeting the protein guidelines for able-bodied athletes. Average caloric intake from fat exceeded current recommendations of 20 to 25 % total energy for the athletic population. In comparison with the lower end of the range for macronutrient, seven of the eight participants were meeting the AMDR for CHO, all were within the AMDR for protein and two were exceeding the AMDR for fat.

## **5.2 Conclusions**

Providing wheelchair athletes with an 8 % CHO beverage during a moderated intensity exercise trial did not improve distance performance during a 30-minute performance trial. The CHO beverage did elicit higher blood glucose levels, RER values and increased the rate of CHO oxidation but it did not alter the participants' ratings of perceived exertion. The research protocol utilized may have negated the impact of the CHO beverage consumed during exercise. Three hours prior to both trials, each participant was instructed to consume a meal which provided them with 2 g CHO·kg<sup>-1</sup> bodyweight. While these instructions are in line with the current pre-exercise guidelines

for able-bodied athletes this pre-exercise CHO meal may have provided them with enough fuel to complete the exercise and performance trial to the best of their physical ability. Therefore with the pre-exercise CHO meal consumed there were no performance benefits to consuming an 8% CHO beverage during the exercise trial.

### **5.3 Recommendations for Future Research**

Ongoing research is needed with wheelchair athletes with varying levels of functional muscle mass in order to develop specific sports nutrition guidelines for optimal performance. With increasing numbers of athletes with SCI or with CP competing in elite level sport, more published information is needed in regards to their dietary patterns. Using a 7-day weighed food records with a large sample of athletes would provide such in depth data. The dietary information could then be compared to physical performance and different dietary manipulation studies could take place. Assessing whether CHO loading strategies work with this specific population would also be very beneficial for endurance athletes. A critical component to determining dietary requirements would be to understand the resting energy requirements and energy needs of daily living of wheelchair athletes. Determining daily energy requirements with the use of doubly labelled water research would provide valuable information for dietitians working in the field of sports nutrition. Dietitians working with specific athletes and teams would be able to develop individual meal plans for optimal performance. In order to identify the main effect of CHO consumption during exercise future research should implement an exercise protocol that begins with the participants in a fasted state. This would eliminate the impact of the CHO energy source at the start of the exercise trial. Having the participants start the exercise in a fasted state would place a greater importance on exogenous glucose since the liver glycogen stores would be lower. This research strategy would perhaps isolate the performance impact of

CHO feeding for wheelchair athletes during exercise. Another approach would be to study the gastric emptying rate in athletes with an SCI to identify if the CHO consumed pre-exercise is still present in the gastrointestinal tract during the early phase of exercise, therefore providing an additional fuel source.

Future research should also monitor body temperature during exercise in order to identify if nutrient or electrolyte beverage composition affects temperature regulation in individuals with impaired sweating abilities. Since each participant in the current study had a unique level of injury, future research should focus on grouping the participants by injury in order to develop guidelines based on specific spinal cord injury levels. With the limited information that is known in regards to fuel metabolism during exercise, more research is needed to identify the impact of exercise intensity on fat oxidation, CHO oxidation, in addition to other blood parameters.



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## Appendix I

### Research Participant Information and Consent Form

**TITLE:** Effect of Carbohydrate ingestion during exercise on performance measures of athletes with spinal cord injury.

**PROTOCOL / STUDY NUMBER:**

**SPONSORSHIP:** This research is being sponsored by the Saskatchewan Academy of Sports medicine (SASM).

**PRINCIPAL INVESTIGATOR:** Carol Rodgers, Ph.D., Dean of the College of Kinesiology, University of Saskatchewan. Phone: 306-966-1061; Email: [carol.rodgers@usask.ca](mailto:carol.rodgers@usask.ca).

Heather Hynes, BSc., MSc. Candidate, student researcher (supervised by Dr. Carol Rodgers) College of Kinesiology, University of Saskatchewan. Phone: 306-249-0171, Email: [heatherhynes@shaw.ca](mailto:heatherhynes@shaw.ca)

Bruce Craven, MSc., Sport Medicine and Science Council of Saskatchewan, Phone 306-975-0848, Email: [cravenb@sasktel.net](mailto:cravenb@sasktel.net).

Gordon Zello, Ph.D., College of Pharmacy and Nutrition, University of Saskatchewan. Phone: 306-966-5825, Email: [gordon.zello@usask.ca](mailto:gordon.zello@usask.ca)

Philip, D. Chilibeck, Ph. D., College of Kinesiology, University of Saskatchewan. Phone: 306-966-1072, Email: [phil.chilibeck@usask.ca](mailto:phil.chilibeck@usask.ca)

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## INTRODUCTION

You are invited to take part in this research study because we want to determine the effect of carbohydrate feeding during moderate intensity exercise on fuel use and performance measures. Before you decide to participate, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts.

**Background information-** Fuel utilization has been researched for several decades resulting in specific carbohydrate (CHO) ingestion guidelines for able bodied athletes involved in endurance and intermittent events. Research in the area of fuel metabolism during aerobic exercise by wheelchair athletes is relatively new. Athletes with a spinal cord injury (SCI) have a loss or impairment of both the sympathetic and parasympathetic response. This altered response may impact the action of major organs and hormones

that play a direct role in substrate metabolism and cardiovascular response to exercise. Encouraging athletes with a SCI to follow the CHO guidelines developed for able body athletes may not be appropriate. To date only three research studies have been published on CHO requirements and exercise in athletes with a SCI, the studies were unable to determine an ideal feeding regime for optimal performance. The proposed study will determine the effects of an 8% CHO beverage during a moderate intensity exercise trial on the performance outcomes, fuel utilization and blood glucose levels of athletes with a SCI.

If you wish to participate, you will be asked to sign this consent form. Your participation is entirely voluntary, so it is up to you to decide whether or not you wish to take part. If you decide to take part in this study, you are free to withdraw at any time without giving reasons for your decision and your refusal to participate will not affect your relationship with any of the researchers.

This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand. You may ask as many questions as you need to understand what the study involves. Please feel free to discuss this with your family, friends or family physician.

#### **STUDY PURPOSE**

The purpose of this proposed research study is to determine the effect of consuming a carbohydrate (CHO) beverage during moderate intensity exercise on the performance outcomes, fuel use and blood glucose levels of athletes with a SCI.

**STUDY PROCEDURES:** If you agree to participate in the study, the following things will occur:

The study will take place over three separate visits to the testing site. Each visit will take between 120 to 150 minutes. The first visit will involve completion of two documents. You will be asked to complete a participant history form that will let the researcher know some background information about your current medical status. You will also be asked to complete a physical activity readiness questionnaire (PAR-Q) that will let the researchers know whether participation in fitness testing is an acceptable thing for you, based on your current health status. Once both of these questionnaires are completed and approved we can then carry on with the remainder of the study.

Collection of anthropometric data; body mass, height, skinfolds, and dual-energy x-ray absorptiometry (DXA) will also take place during the first visit. The body mass will be taken with a platform scale that measures to the 0.05 of a kilogram; height will be measured with you, the participants in a supine position (measured to the nearest centimetre). Skinfold measures will be taken from four sites on the right side of the body; specifically, biceps, triceps, suprailiac, and subscapular. Each site will be

measured 3 times and the mean score will be used for analysis. A technician will carry out a DXA scan. The scan is a non-invasive test, which provides precise measurements of bone density, lean tissue mass, and total and regional body fat. The DXA unit uses very low dose x-rays of two different levels to distinguish between bone and soft tissue. DXA has been used to assess the body composition of athletes with SCI in previous research.

The first visit will also include a fitness test, a  $VO_{2max}$  test, which tests your aerobic fitness. Your aerobic fitness is your body's capability to deliver oxygen to your working muscles while you are exercising on a stationary wheelchair roller- added in (indoor 200m track- removed). Removed-(Your aerobic fitness will be measured using an adapted Leger and Boucher test. Pylons will be used to mark off every 50 meters around the track) Following test instructions and warm up, you will be asked to propel your wheelchair on the roller at increasing speeds until you are not able to go any faster. The  $VO_2$  protocol will start at an initial speed of 4km/ hour for 1 minute and then increase by 1 km/hour every minute until exhaustion is noted. The pylons will be used as speed markers(removed). During the test you will breath into a mouthpiece so that the gas composition of your breath can be determined. The exercise test itself will take approximately 10 to 15 minutes but please allow for an hour to become familiar with the procedures and prepare for the test.

After the completion of the exercise test you will be provided with detailed instruction on the completion of a 3-day food and activity log. By completing the 3-day log, the researchers can determine your average nutrient intake and activity patterns. The 3-day food and activity log will also be used as a guide between your second and third visits so that your food intake and activity patterns are consistent before each trial.

The female participants will be asked about their menstrual cycle because different stages of menstruation can impact the way the body uses energy during exercise. To account for this factor, the female participants will be tested at predetermined times during their menstrual cycle.

A research assistant otherwise not involved with the research project will give you a number. That number code system will be kept until the completion of data collection. The participants will be separated by gender and then each gender will be placed into two groups by random selection (i.e. by chance by a computer) under double blind conditions. The term double-blind conditions means that neither the research participants nor the research team will know which treatment the research participant is receiving, but that information will be made available in the event of a medical emergency. This method will be used to ensure that the gender distribution is equal between both groups. Half of the group (8 participants) will receive the treatment first and the other half (8 participants) will receive the placebo first. Group 1 will receive the treatment beverage during exercise trial #1 and group 2 will receive the treatment beverage during exercise trial #2. You are doing the exercise trial once with the treatment beverage and once with the placebo beverage so that we can compare the differences between your two trials.

All the participants will complete the same exercise and performance trial. The exercise



and performance trial will be conducted on a stationary wheelchair roller (removed-200m indoor track). You will be seated in your own racing and/or competition wheelchairs. The exercise trial is 1 hour at 65%  $\text{VO}_{2\text{ max}}$  followed immediately by a 30-minute performance trial in which distance covered (km) will be measured. During the 30-minute performance trial you will be encouraged to cover as much distance as possible. The distance will be measured by a digital bike computer. During the exercise trial you will be asked to rate your level of exertion using Borg's scale of rate of perceived exertion (RPE). This scale will be given to you at 20, 40, 60 minute mark of the 65%  $\text{VO}_{2\text{ max}}$  exercise trial and at the completion of the 30-minute performance trial.

After both of the 65%  $\text{VO}_{2\text{ max}}$  exercise trials you will be required to perform a 5 second maximal contraction of your triceps muscle while the electric activity from your muscles is assessed. This assessment will involve the placement of electrode "stickers" on the skin over your triceps muscle and a computer wired to the electrodes will measure the electrical activity. This is to determine your nervous system's ability to activate your muscles.

The two exercise trials will be held seven days apart. A research assistant, not otherwise involved in the study will measure the treatment and placebo powders to ensure that neither the researcher nor the participants will be aware of the beverage composition. The treatment beverage will be 200ml of an 8% CHO (8 grams of CHO per 100ml of water) ingested every 15 minutes during the 1 hour trial (at the 15, 30, 45, 60 minute mark); for a total of 64 grams of CHO. The placebo beverage will be the same color and contain a non-caloric sweetener.

During the test you will breath into a mouthpiece so that the gas composition of your breath can be determined. Heart rate will also be monitored throughout the trial used a heart rate monitor. Blood glucose and blood lactate will be measured 10 minutes before the exercise trial and every 20 minutes during the hour at 65%  $\text{VO}_{2\text{ max}}$ . Blood glucose will be analysed using a portable glucometer. A finger will be pricked and a drop of blood (0.6 microlitre) is then put on the test strip. The blood glucose meters and testing strips were selected because they are portable and only require small blood sample of 0.6  $\mu\text{L}$ . Blood lactate will be analysed by an Accusport<sup>TM</sup> Portable Lactate Analyzer. During the 30-minute performance trial blood samples will not be taken. Immediately after the 30-minute performance trial and at 2, 5, and at 10 minutes post blood samples will be taken and analysed for glucose and lactate levels.

## **BENEFITS**

If you choose to participate in this study, there may or may not be direct benefits to you. By participating in this study you will have the opportunity to gain information about your current body composition, dietary intake patterns, and fitness level. Also, it is possible that with the carbohydrate feeding your aerobic training will improve. These benefits, however, are not guaranteed.

## **RISKS AND DISCOMFORTS**

While on this study, you may experience some discomfort due to the ingestion of the

treatment beverages during the exercise trials. The exercise tests may cause you some discomfort because they will be performed to exhaustion. Injuries that may result include: muscle pulls, strains and or cramps, but this will be minimized by having you perform a proper warm up before the exercise tests. There is a possibility that you will feel muscle or joint soreness in the days following your exercise testing.

**There may be unknown or unforeseen risks during the study or after the study is completed.**

### **COST AND REIMBURSEMENTS**

There will be no cost to you for your participation in this study. You will not be charged for any research procedures. There will be no reimbursements for time commitments or pocket expenses such as transportation.

### **RESEARCH-RELATED INJURY**

In the case of a medical emergency related to the study, you should seek immediate care and, as soon as possible, notify the study doctor. Necessary medical treatment will be made available at no cost to you. By signing this document, you do not waive any of your legal rights.

### **CONFIDENTIALITY**

While absolute confidentiality cannot be guaranteed, every effort to make certain that your participation in this study, and information gathered during the study period will be kept confidential will be made. The research staff will do everything possible to keep your personal information confidential. Your name will not be used at all in the study records. Instead, a special number (which may include your initials and date of birth but not your name or address) will be used. All data and information regarding the study will be kept together, locked in a cabinet in the College of Kinesiology for a period of twenty-five years, in the care of the principle investigator, Dr. Carol Rodgers. All reporting of data in presentations and /or publication format will be done in aggregate form and will not refer directly to individual data.

### **VOLUNTARY WITHDRAWAL FROM THE STUDY**

If you do decide to take part in this study, you are still free to withdraw at any time and without giving reasons for your decision. There will be no penalty or loss of benefits to which you are otherwise entitled, and your future medical care will not be affected. If you are a student at the University of Saskatchewan, refusal to participate or withdrawal from the study will not affect your academic standing or relationship with University instructors.

If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during enrolment in the study will be retained for analysis up to the point of your withdrawal.

## **CONTACT INFORMATION**

If you have questions concerning the study you can contact Dr. Carol Rodgers (principle investigator) at 306-966-1061 or Heather Hynes (student researcher) at 306-249-0171

If you have questions about your rights as a research subject, you can contact the Chair of Biomedical Research Ethics Board, c/o Ethics Office, University of Saskatchewan, at 306-966-4053.

We will advise you of any new information that will have bearing on your decision to continue in this study.

This study has been reviewed and approved on ethical grounds by the University of Saskatchewan Biomedical Research Ethics Board. The Research Ethics Board reviews human research studies. It protects the rights and welfare of the people taking part in those studies.

## **CONSENT TO PARTICIPATE**

By signing below, I acknowledge that I have read or have had this read to me and that I understand the research subject information, the study procedures, and the consent form. I understand that my participation in this study is voluntary and that we can withdraw from the study at any time without penalty. I was given sufficient time to think about it. I had the opportunity to ask questions and have received satisfactory answers to all of my questions. I have received a copy of the consent form for my own purposes.

By signing this document I do not waive any of my legal rights. I will be given a signed copy of this consent form.

Participant's signature: \_\_\_\_\_

Date: \_\_\_\_\_.

Researcher's signature: \_\_\_\_\_

Date: \_\_\_\_\_.

## Appendix II

NOV-20 2007 10:23

UNIVERSITY OF SASKATCHEWAN

Biomedical Research Ethics Board (Bio-REB)

### Certificate of Approval

PRINCIPAL INVESTIGATOR Carol Rodgers	DEPARTMENT Kinesiology	Sto # 07-176
---	---------------------------	-----------------

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT  
College of Kinesiology  
105 Gymnasium Place  
Saskatoon SK S7N 5C2

SUB-INVESTIGATOR(S)  
Philip D. Chilibeck, Gordon A. Zello

STUDENT RESEARCHERS  
Bruce Craven, Heather Hynes

SPONSORING AGENCIES  
SASKATCHEWAN ACADEMY OF SPORTS MEDICINE

TITLE: Effect of Carbohydrate Ingestion During Exercise on Performance Measure of Athletes with Spinal Cord Injuries

APPROVAL DATE 19-Nov-2007	EXPIRY DATE 18-Nov-2008	APPROVAL OF Researcher's Summary (16-Nov-2007) Research Participant Information and Consent Form (18-Nov-2007)
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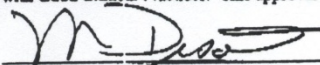
Full Board Meeting ☐

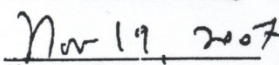
Delegated Review ☒

**CERTIFICATION**  
The study is acceptable on scientific and ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research study, and for ensuring that the authorized research is carried out according to governing law. This approval is valid for the specified period provided there is no change to the approved protocol or consent process.

**FIRST TIME REVIEW AND CONTINUING APPROVAL**  
The University of Saskatchewan Biomedical Research Ethics Board reviews above minimal studies at a full-board (face-to-face) meeting. Any research classified as minimal risk is reviewed through the delegated (subcommittee) review process. The initial Certificate of Approval includes the approval period the REB has assigned to a study. The Status Report form must be submitted within one month prior to the assigned expiry date. The researcher shall indicate to the REB any specific requirements of the sponsoring organizations (e.g. requirement for full-board review and approval) for the continuing review process deemed necessary for that project. For more information visit [http://www.usask.ca/research/ethics\\_review/](http://www.usask.ca/research/ethics_review/).

**REB ATTESTATION**  
In respect to clinical trials, the University of Saskatchewan Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations and carries out its functions in a manner consistent with Good Clinical Practices. This approval and the views of this REB have been documented in writing.

  
Michel Desautels, Ph.D., Chair  
University of Saskatchewan  
Biomedical Research Ethics Board

  
Signature Date

Please send all correspondence to:  
Ethics Office  
University of Saskatchewan  
Room 305 Kirk Hall, 117 Science Place  
Saskatoon SK S7N 5C8

TOTAL P.02

**Appendix III**  
**Participant History Form**

Name: \_\_\_\_\_  
Date of Birth: \_\_\_\_\_  
Gender: \_\_\_\_\_  
Sport Classification: \_\_\_\_\_  
Height: \_\_\_\_\_  
Current Bodyweight: \_\_\_\_\_

**Please answer the following questions:**

**History of present injury:**

1. Please state the level of your spinal cord injury (example: T12, T5, or Spina Bifida):  
\_\_\_\_\_
2. Please state the number of years since your spinal cord injury:  
\_\_\_\_\_
3. Please state if you currently have any current complications due to your spinal cord injury: \_\_\_\_\_  
\_\_\_\_\_

**Medications & Supplements:**

4. Are you currently taking any supplements (vitamin, mineral, herbs, etc.)?  
Yes/No  
a. If Yes, please state with supplements: \_\_\_\_\_  
\_\_\_\_\_
5. Are you currently taking any medications? Yes/No  
a. If Yes, please state which medications: \_\_\_\_\_  
\_\_\_\_\_

**Sport Involvement:**

Please state the number of years that you have been involved in sport and which sport(s) you have participated in: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Thank you.

# PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of any other reason why you should not do physical activity?

If  
you  
answered

## YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

## NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

### DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

**PLEASE NOTE:** If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

**Informed Use of the PAR-Q:** The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

**No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.**

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME \_\_\_\_\_

SIGNATURE \_\_\_\_\_

DATE \_\_\_\_\_

SIGNATURE OF PARENT  
or GUARDIAN (for participants under the age of majority) \_\_\_\_\_

WITNESS \_\_\_\_\_

**Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.**



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continued on other side...



[illegible]

- `primes = 1..10`
- `k = 100000`
- `1..k`
- `HighLevelPrimes`
- `JuliaNewPrimes`
- `new_prime`
- `new_k`
- `1..new_k`
- `1..new_k`

Play all 20 songs!

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## - Q. 111 (Renze 2002).



## Appendix IV

### Instructions for Documenting Food, Fluid & Activity Recording Forms

**Name:** \_\_\_\_\_

**Dates to Keep Your Food & Fluid Records Are:** \_\_\_\_\_

**Competitive Sport (e.g. athletics):** \_\_\_\_\_

**Competitive Event (e.g. 800 m):** \_\_\_\_\_

1. Record your food and fluid intake for each of the **3** days.
2. Record all of your training and activities conducted for each of the **3** days.
3. Provide as many details about your food & fluid choices as possible. For example, if you had a sandwich please indicate what was in the sandwich, i.e. 1 teaspoon mustard, 1 lettuce leaf, ½ tomato, 60 grams oven roasted turkey, 2 slices whole wheat bread, etc.; OR, if you ate a bowl of cereal, was it dry cereal or did you add milk, and if so, what kind of milk, 1%, skim, etc.? What was the size of your bowl?
4. Initially serve yourself your usual food/fluid portion and then measure the food or fluid item to the best of your ability.
5. Indicate the precise volume of a beverage, rather than stating “one glass”, indicate the volume- 250ml, 500ml, etc.
6. Record how a food was prepared, e.g. pan fried, barbecued, broiled, boiled, steamed, oils added, etc.
7. Did you add any condiments (i.e. catsup, salad dressing, butter, etc.) to your foods?
8. Wherever possible record the commercial product names, e.g., Eggo plain frozen waffles, Quaker Plain Instant Oatmeal, Gatorade powder, etc.
9. Don't forget to record all fluids consumed from sport drinks and coffee to water and 1% milk.



## FOOD, FLUID & ACTIVITY RECORDING FORM—EXAMPLE

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### **Training activity for this day:**

Activity type: ☐ Aerobic training ☐ Strength training ☐ Mixed aerobic and strength training

Other type of

Activity: \_\_\_\_\_

Activity intensity: ☐ Low ☐ Medium ☐ High

Activity duration (hours): \_\_\_\_\_

When did you train today: \_\_\_\_\_

<b>Time</b>	<b>Food / Fluid / Food Brand Names</b>	<b><i>Amount Size</i></b>

## Appendix V

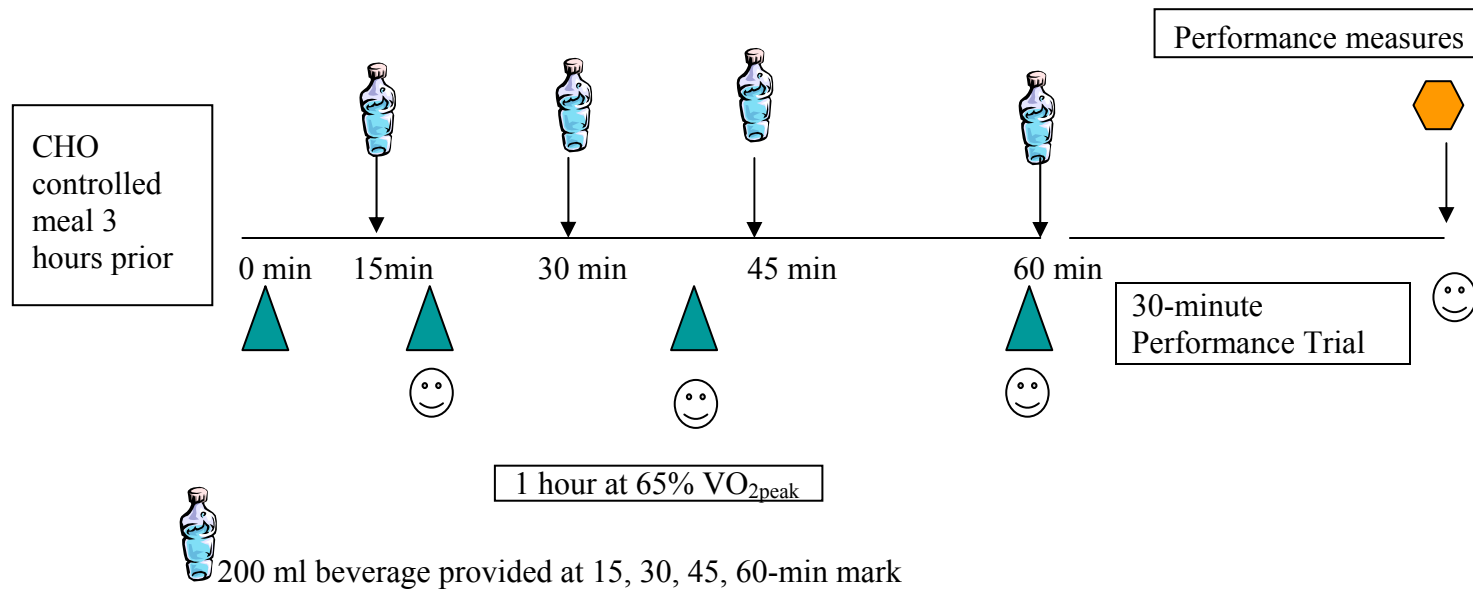
### EXERCISE TRIAL & PERFORMANCE TRIAL



Heart rate- monitored continuously



Metabolic Cart – monitored for 5-minute time periods during the 60-minute exercise trial and continuous monitoring during the 30-minute performance trial.



Blood glucose and blood lactate immediately post, and 2, 5, 10-min post performance trial



Blood glucose and Lactate at pre-exercise, 20, 40, 60-min mark



RPE at 20, 40, 60-min mark and at the completion of the performance trial

## **Appendix VI**

Pre-Exercise Meals: Goal intake **3 hours prior** to the exercise trial is 1 to 4 grams carbohydrate (CHO)/kg Bodyweight (BW) \*\* amount set at  $2\text{g}\cdot\text{kg}^{-1}$  BW

**IMPORTANT- After your meal do not consume any food or fluids (with calories)**

1. Current BW of 50 to 60 Kg: **100 to 120 grams CHO**  
**Meal: 500ml Fruit juice (56 g) + 2 slices bread (28 g) + 1 Tbsp Jam (14 g) + 1 Tbsp peanut butter (3g)**
2. Current BW of 61 to 70 Kg: **122 to 140 grams CHO**  
**Meal: 500ml Fruit juice (56g) + 2 slices bread (28 g) + 1 Tbsp Jam (14 g) + 1 Tbsp peanut butter (3 g) + 1 banana (27 g)**
3. Current BW of 71 to 80 kg: **142 to 160 grams CHO**  
**Meal: 500ml Fruit juice (56g) + 3 slices bread (42 g) + 2 Tbsp Jam (28 g) + 1 Tbsp peanut butter (3 g) + 1 banana (27 g)**
4. Current BW of 90 to 100 kg: **180 to 200 grams CHO**  
**Meal: 500ml Fruit juice (56g) + 4 slices bread (56 g) + 2 Tbsp Jam (28 g) + 1 Tbsp peanut butter (3 g) + 1 banana (27 g) +  $\frac{1}{2}$  cup applesauce (sweetened) (27 g)**

## Appendix VII

### Results- Distance Values (km) and % VO<sub>2peak</sub> Values

#### Total distance covered during 60-minute exercise trial

Participant code	CHO beverage trial (km)	Placebo beverage trial (km)
1	9.44	8.69
2	8.06	8.53
3	7.13	7.12
4	12.32	12.10
5	8.75	8.48
6	6.90	6.62
7	6.58	6.50
8	7.21	7.12
Mean $\pm$ SD	8.29 $\pm$ 1.89	8.14 $\pm$ 1.83

Individual results presented, means  $\pm$  SD (n=8). Carbohydrates (CHO).

#### %VO<sub>2peak</sub> for the 60-minute exercise trial

# code	% VO <sub>2 peak</sub> CHO Trial	% VO <sub>2 peak</sub> Placebo Trial
1	57	55
2	48	49
3	66	66
4	52	59
5	57	58
6	64	62
7	64	61
8	51	47
Mean $\pm$ SD	57 $\pm$ 6	57 $\pm$ 7

Individual results presented, means  $\pm$  SD (n=8).

**%VO<sub>2peak</sub> for the 30-minute performance trial**

# code	% VO <sub>2 peak</sub> CHO Trial	% VO <sub>2 peak</sub> Placebo Trial
1	78	79
2	68	77
3	78	76
4	65	77
5	95	88
6	121	100
7	79	80
8	56	51
Mean ± SD	80 ± 20	79 ± 14

Individual results presented, means ± SD (n=8).

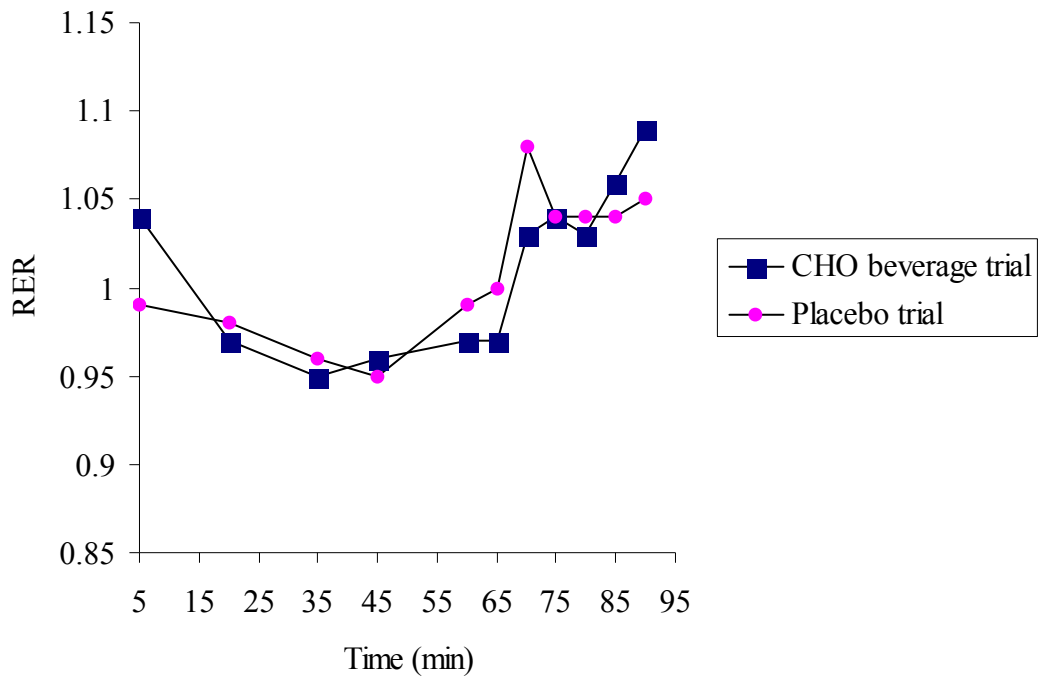
## Appendix VIII

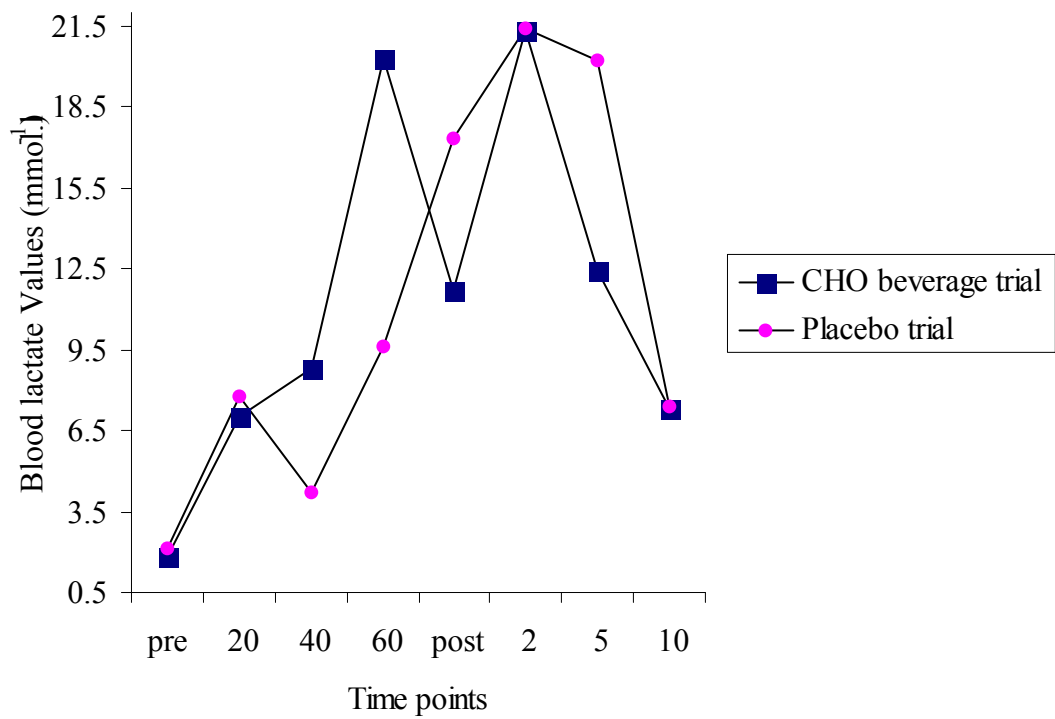
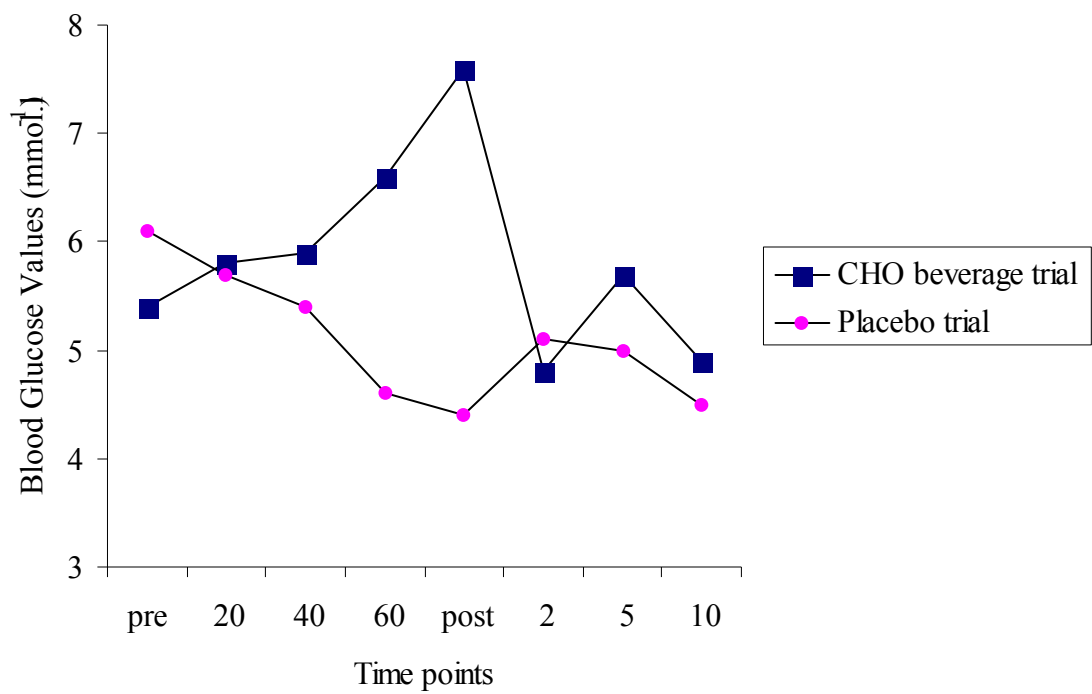
Participant 1: Male, 45yrs, SCI T4, 79 Kg, 165cm

Distance Results:

Trial #	Drink #	60-min Distance (km)	Average Speed ( $\text{km}\cdot\text{h}^{-1}$ )	Max Speed ( $\text{km}\cdot\text{h}^{-1}$ )	P-Distance (km)	P-Avs ( $\text{km}\cdot\text{h}^{-1}$ )	P-Mxs ( $\text{km}\cdot\text{h}^{-1}$ )
1	CHO	9.4	9.4	12.3	6.2	12.2	16.1
2	Placebo	8.7	8.6	12.3	6.4	12.8	16.1

30-min Performance trial (P), Average Speed (Avs), Maximal speed (Mxs)



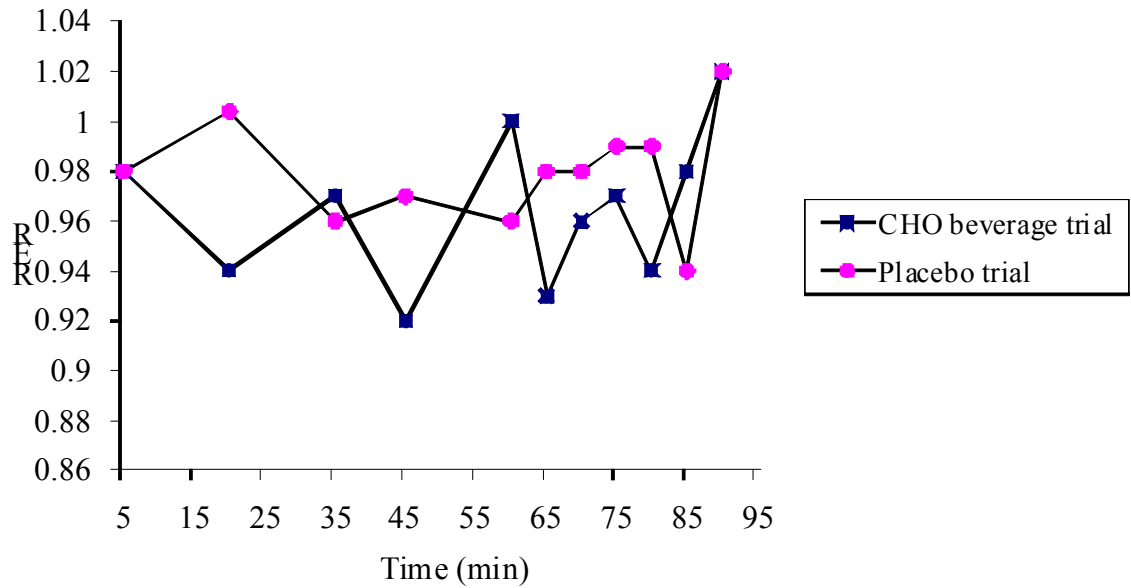


Participant 2: Male, 28 yrs, CP, 72 Kg, 168.5 cm

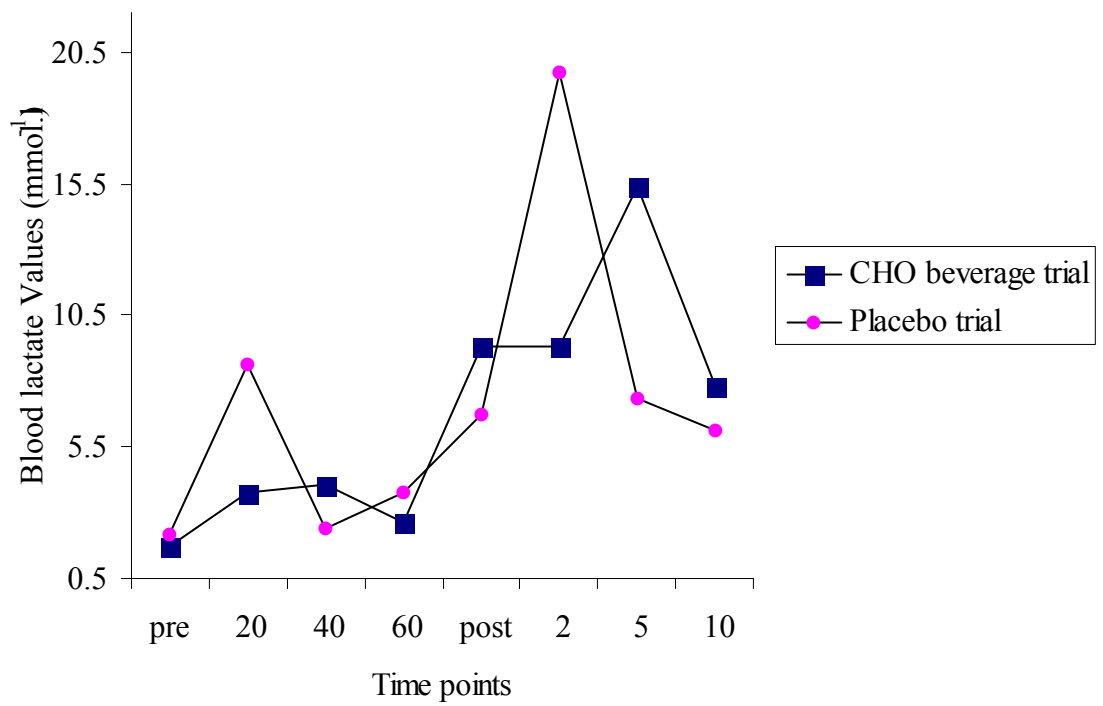
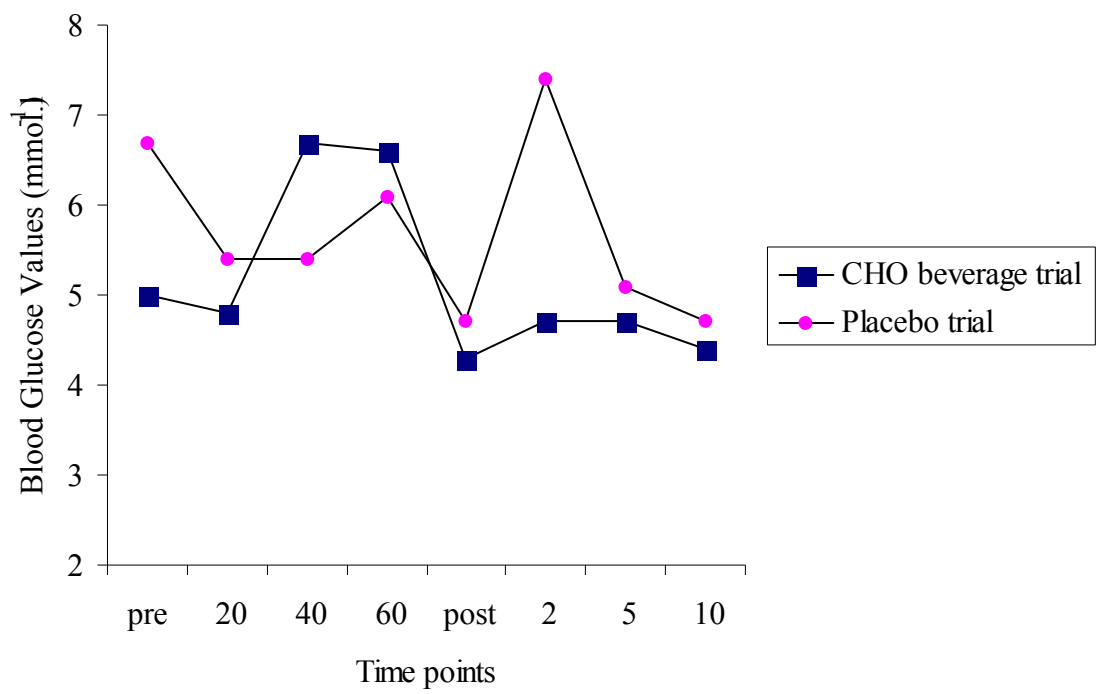
Distance Results:

Trial #	Drink #	60-min Distance (km)	Average Speed (km·h <sup>-1</sup> )	Max Speed (km·h <sup>-1</sup> )	P-Distance (km)	P-Avs (km·h <sup>-1</sup> )	P-Mxs (km·h <sup>-1</sup> )
1	CHO	8.1	8	11.7	5.3	10.4	17.9
2	Placebo	8.53	8	12	5.5	11	19.5

30-min Performance trial (P), Average Speed (Avs), Maximal speed (Mxs)







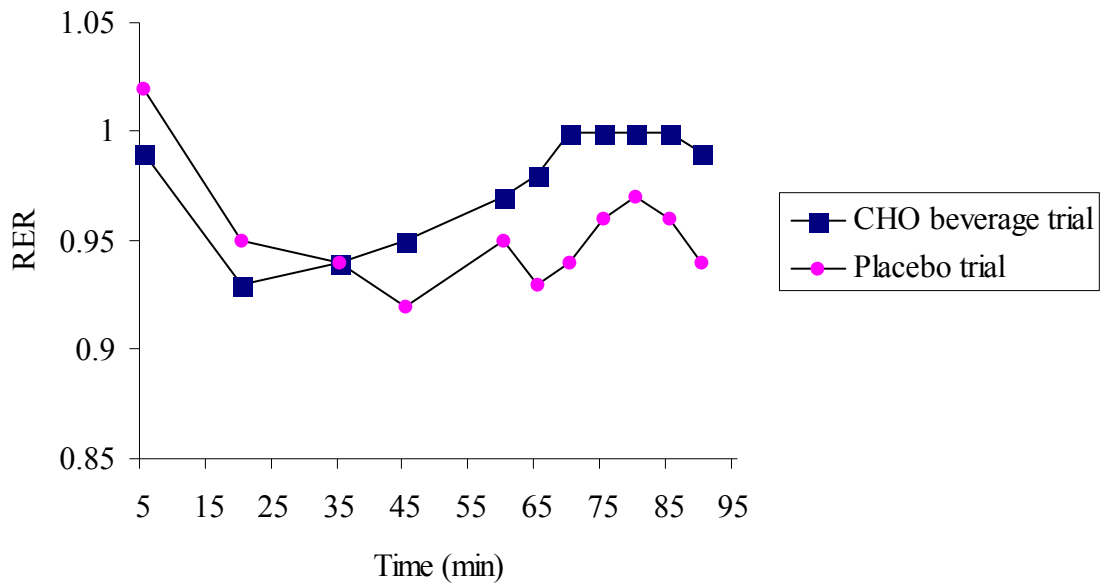
Participant 3: Female, 27 yrs, SCI T1, 53 Kg, 151 cm

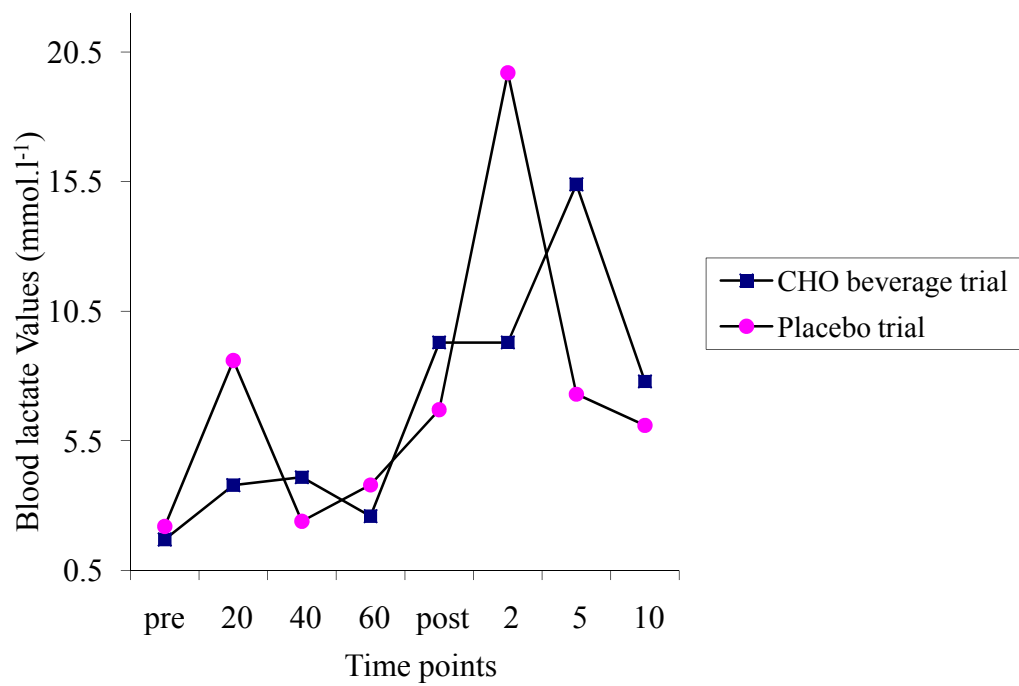
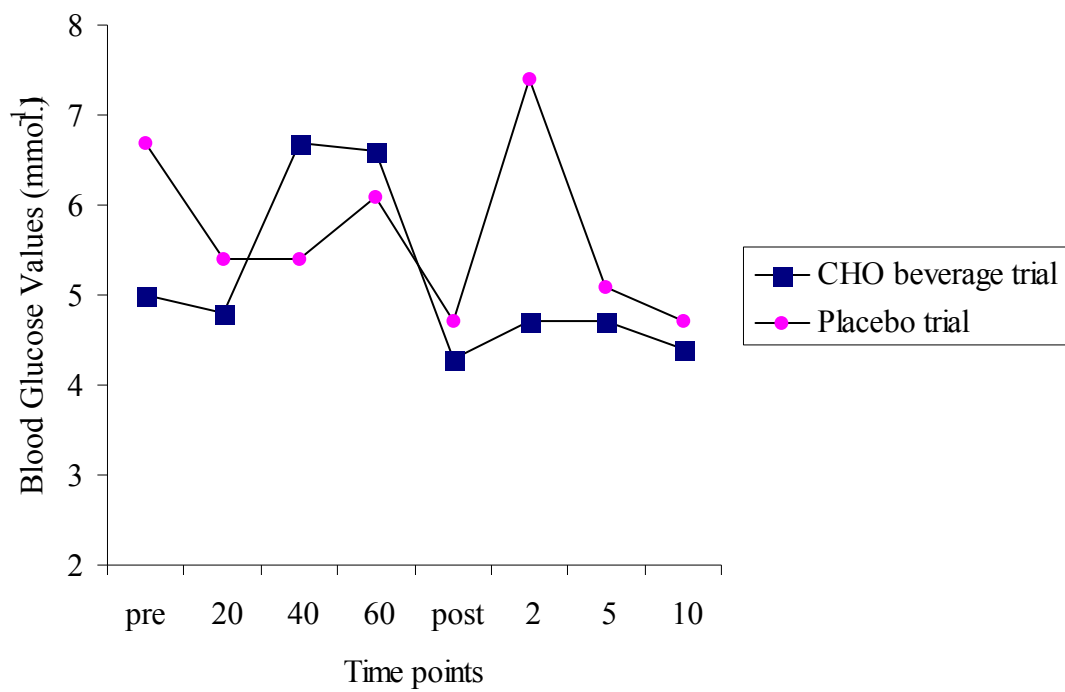
#### Distance Results:

Trial #	Drink #	60-min Distance (km)	Average Speed ( $\text{km}\cdot\text{h}^{-1}$ )	Max Speed ( $\text{km}\cdot\text{h}^{-1}$ )	P-Distance (km)	P-Avs ( $\text{km}\cdot\text{h}^{-1}$ )	P-Mxs ( $\text{km}\cdot\text{h}^{-1}$ )
1	CHO	7.1	7.1	10.3	4.35	8.6	11.6
2	Placebo	7.1	7.1	10.5	4.41	8.8	10.9

30-min Performance trial (P), Average Speed (Avs), Maximal speed (Mxs)

Athlete overheated during trial #2 with the placebo beverage at 12 minutes into performance trial.



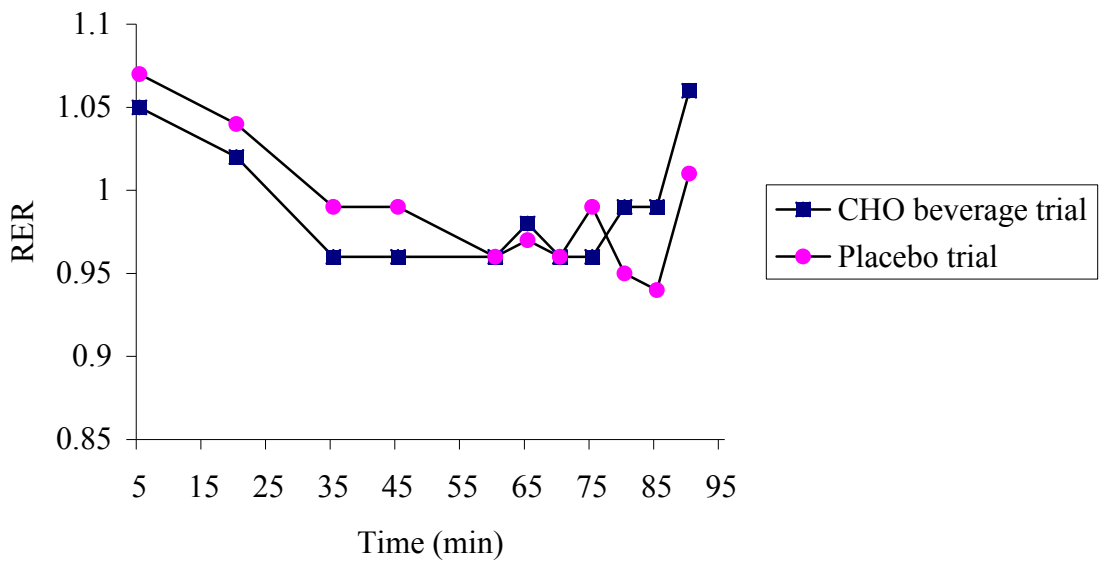


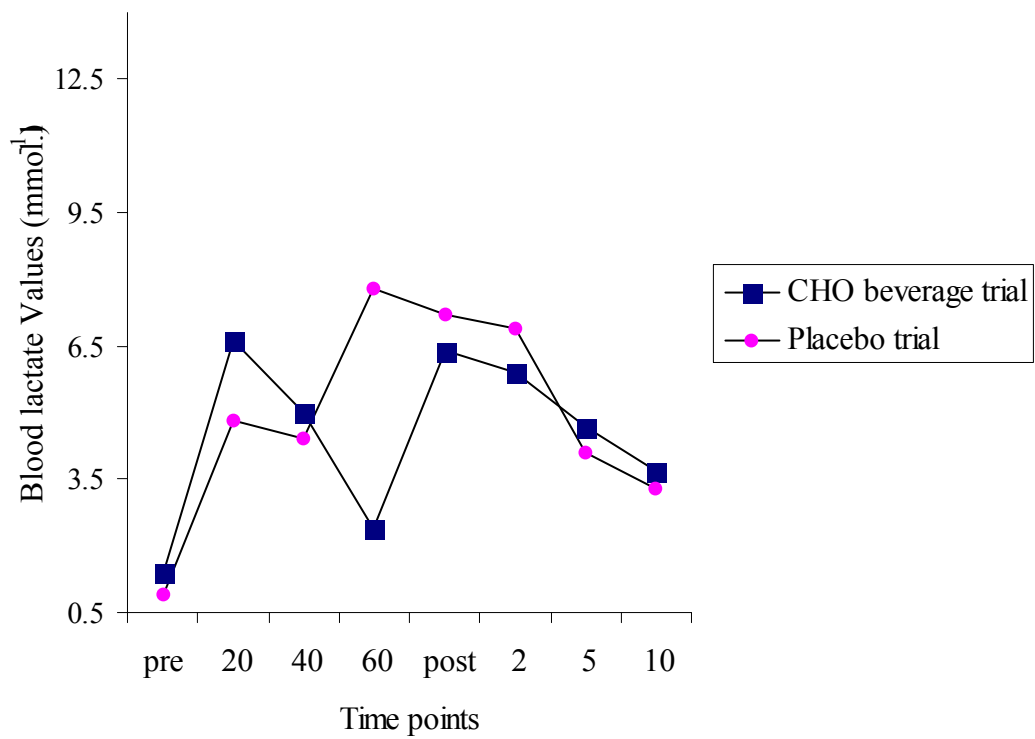
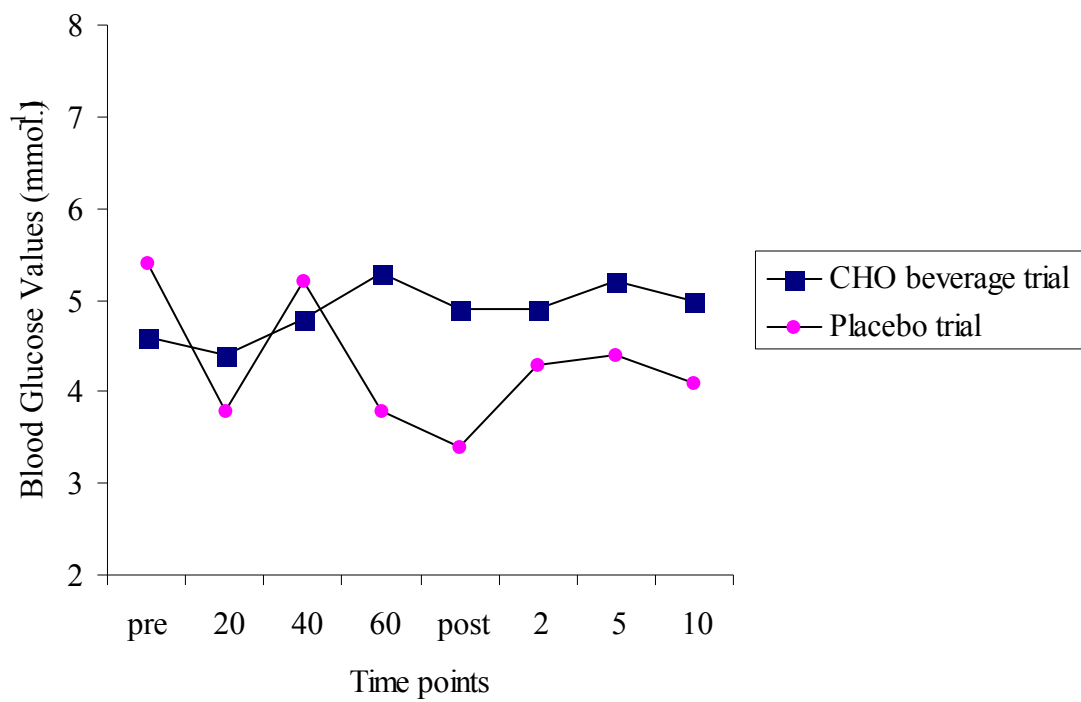
Participant 4: Male, 24 yrs, SCI L1, 93 Kg, 180 cm

Distance Results:

Trial #	Drink #	60-min Distance (km)	Average Speed (km·h <sup>-1</sup> )	Max Speed (km·h <sup>-1</sup> )	P-Distance (km)	P-Avs (km·h <sup>-1</sup> )	P-Mxs (km·h <sup>-1</sup> )
1	Placebo	12.1	11.7	14.5	7.28	14.4	16.7
2	CHO	12.3	12.3	14.7	7.20	14.4	17.4

30-min Performance trial (P), Average Speed (Avs), Maximal speed (Mxs)



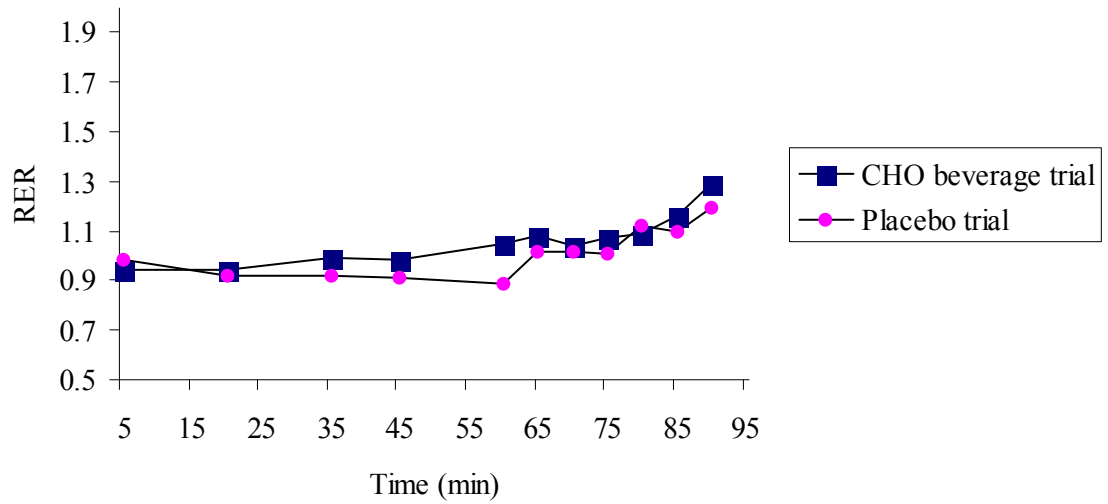


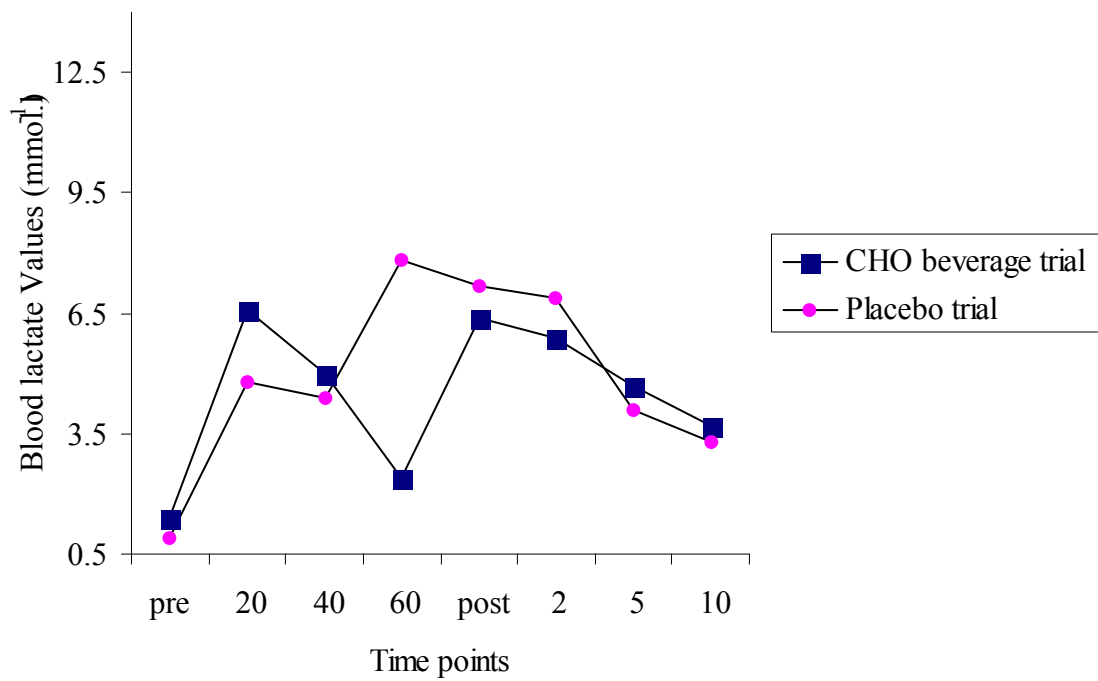
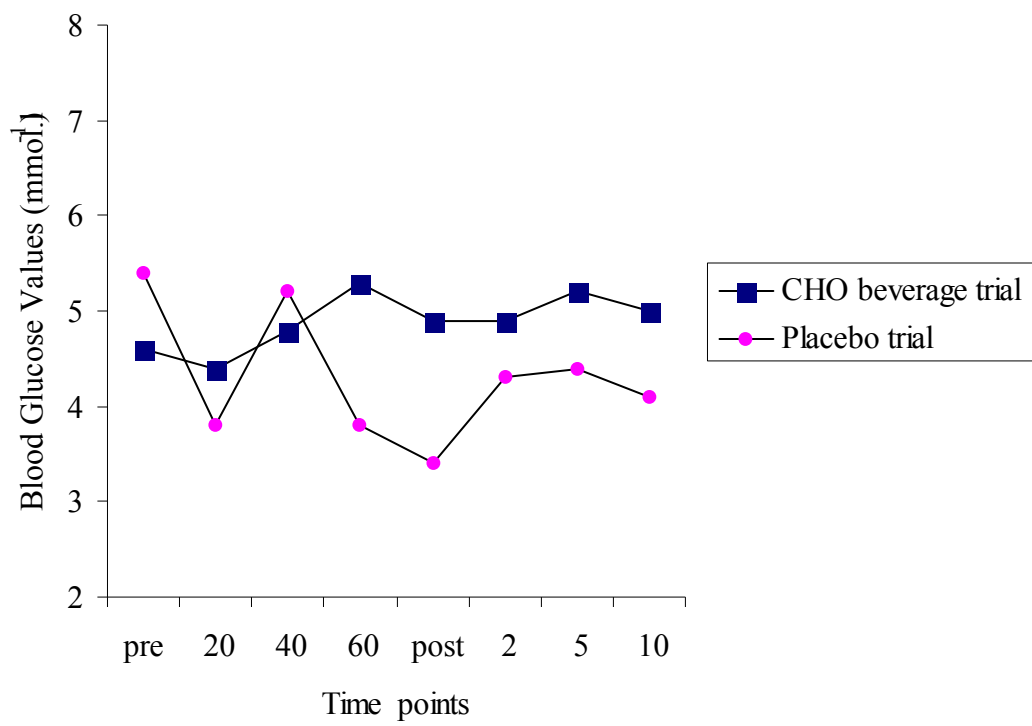
Participant 5: Male, 43 yrs, SCI T3, 84 Kg, 189 cm

Distance Results:

Trial #	Drink #	60-min Distance (km)	Average Speed ( $\text{km}\cdot\text{h}^{-1}$ )	Max Speed ( $\text{km}\cdot\text{h}^{-1}$ )	P-Distance (km)	P-Avs ( $\text{km}\cdot\text{h}^{-1}$ )	P-Mxs ( $\text{km}\cdot\text{h}^{-1}$ )
1	Placebo	8.48	8.4	10.5	6.40	12.8	15.5
2	CHO	8.75	8.7	11.9	6.42	12.8	16.1

30-min Performance trial (P), Average Speed (Avs), Maximal speed (Mxs)





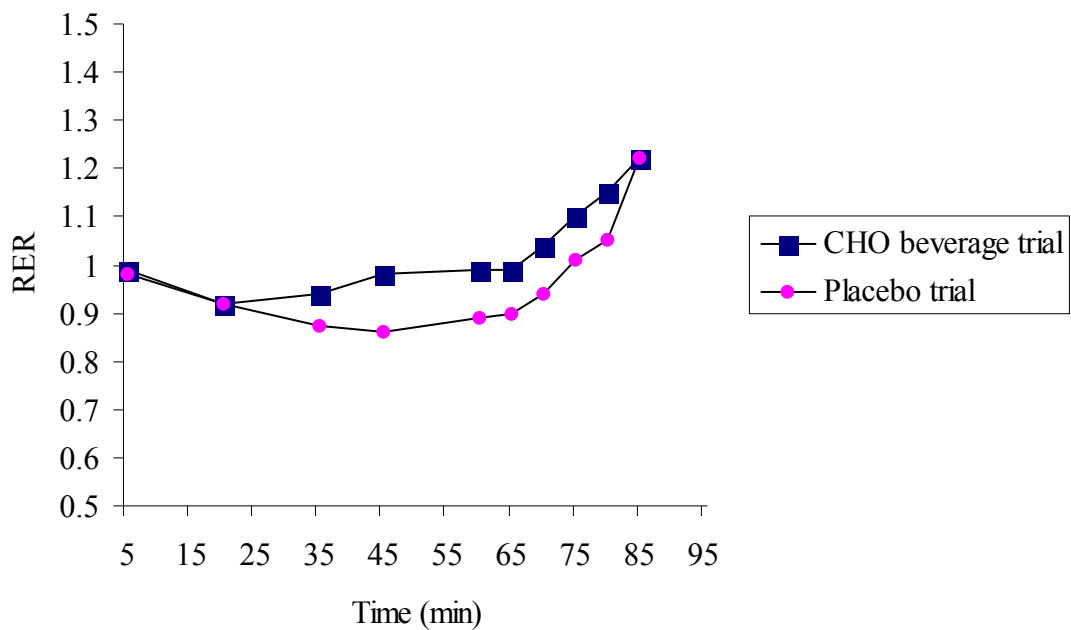
Participant 6: Male, 44 yrs, SCI C6, 68 Kg, 182 cm

#### Distance Results:

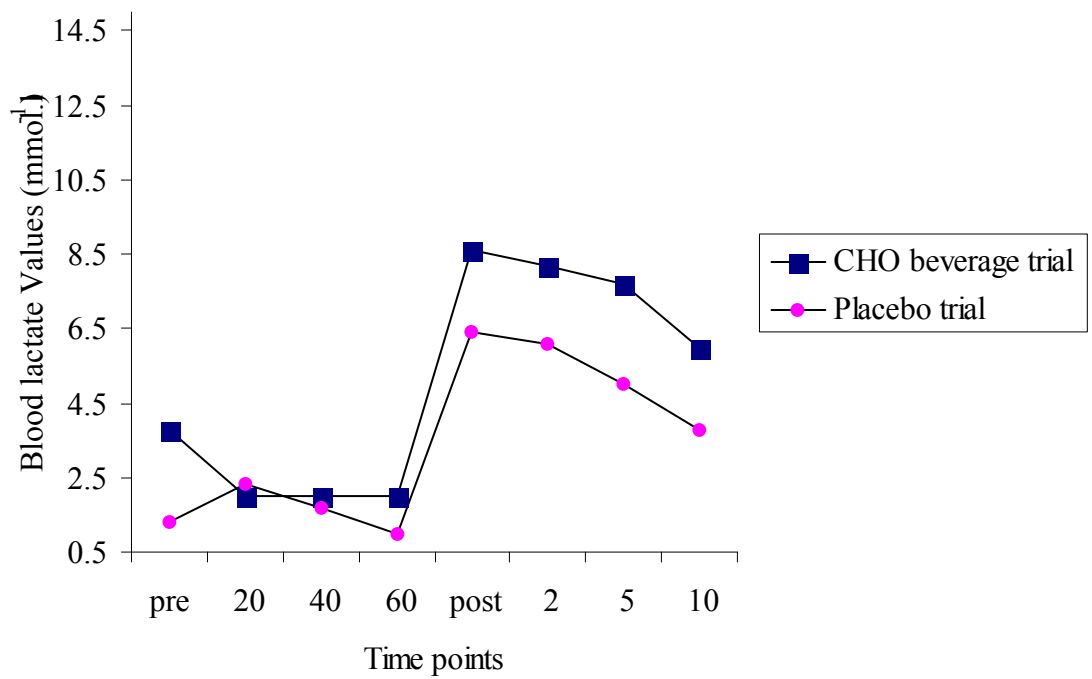
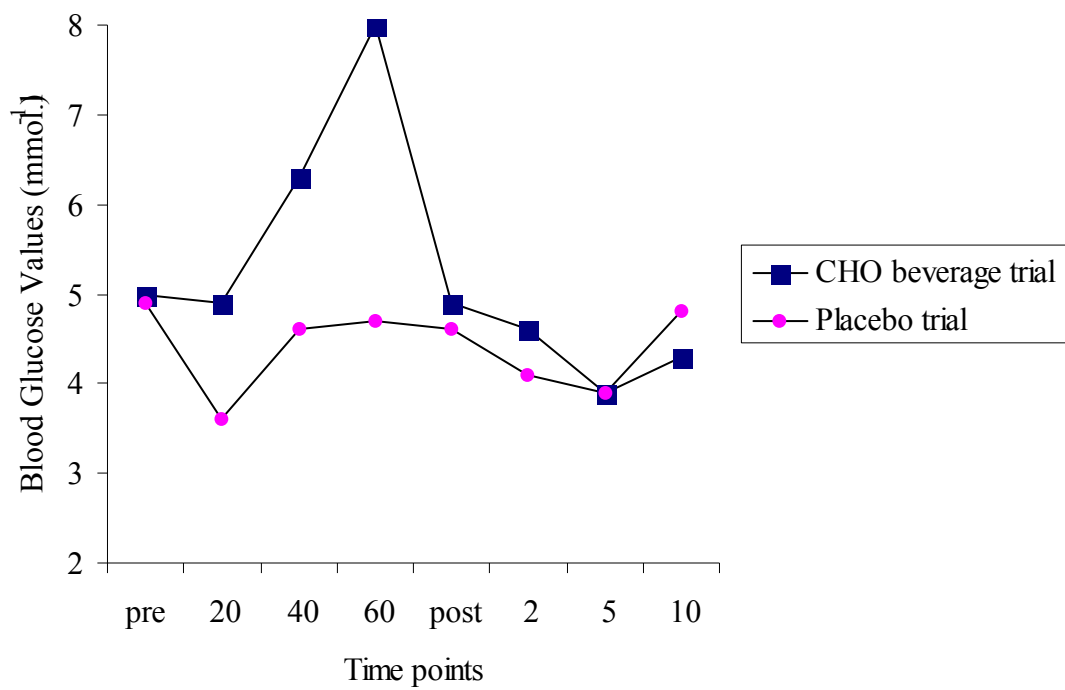
Trial #	Drink #	60-min Distance (km)	Average Speed ( $\text{km}\cdot\text{h}^{-1}$ )	Max Speed ( $\text{km}\cdot\text{h}^{-1}$ )	P-Distance (km)	P-Avs ( $\text{km}\cdot\text{h}^{-1}$ )	P-Mxs ( $\text{km}\cdot\text{h}^{-1}$ )
1	Placebo	6.62	6.60	11.3	4.39	11.4	15.8
2	CHO	6.90	6.90	9.1	4.56	12.0	16.6

30-min Performance trial (P), Average Speed (Avs), Maximal speed (Mxs)

Both performance trials were 22:33.00 minutes in duration. The participant could not complete the 30-minute trial.







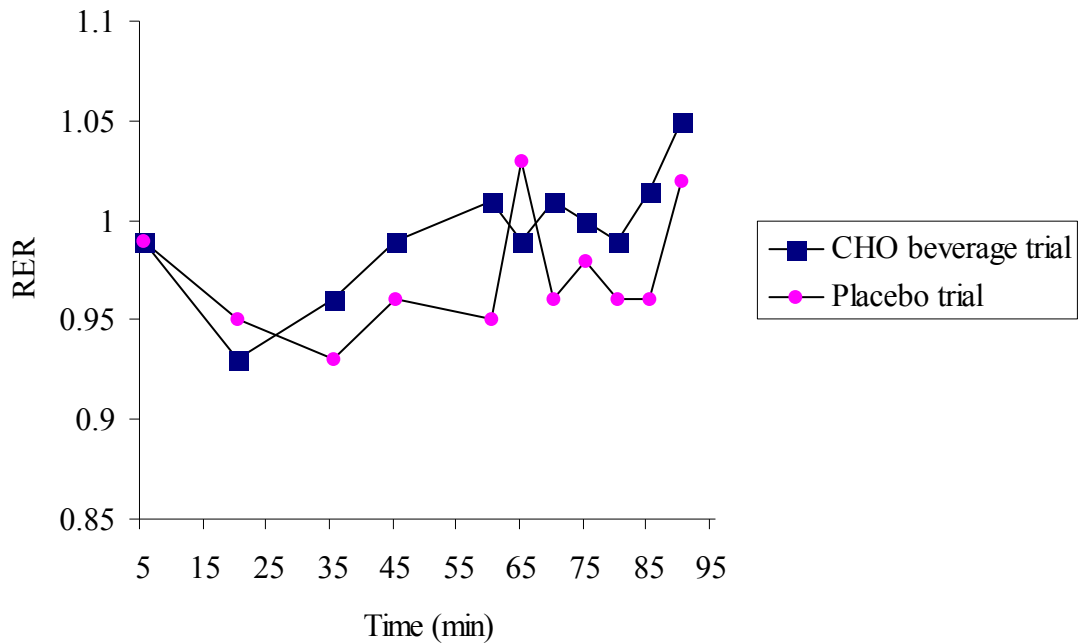
Participant 7: Male, 41 yrs, SCI C5-6, 90.7 Kg, 188 cm

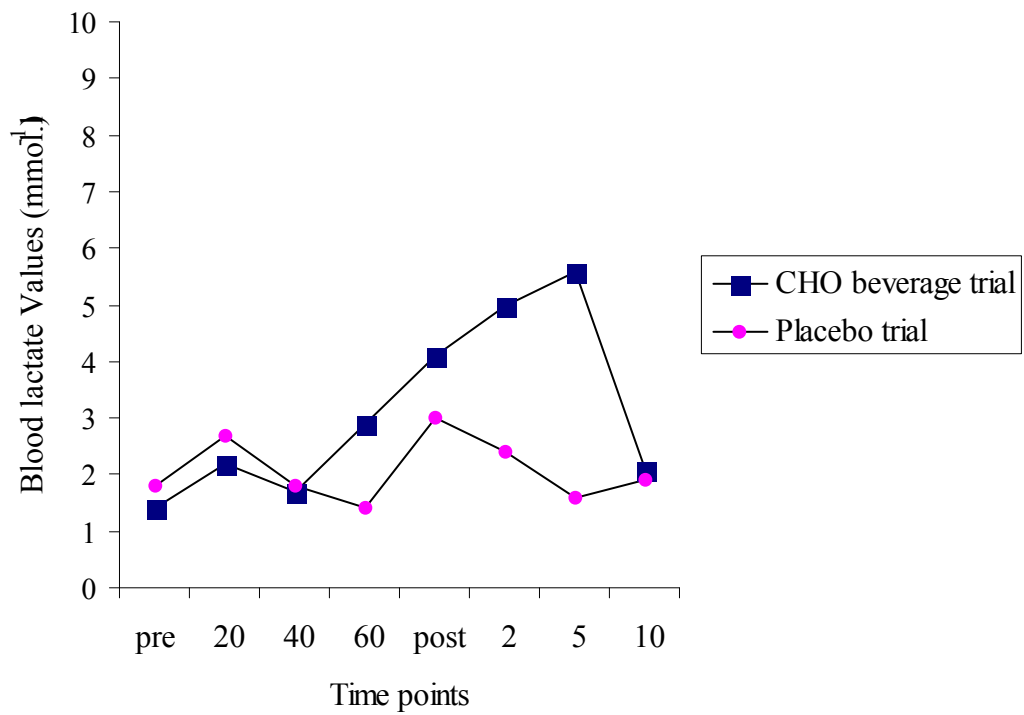
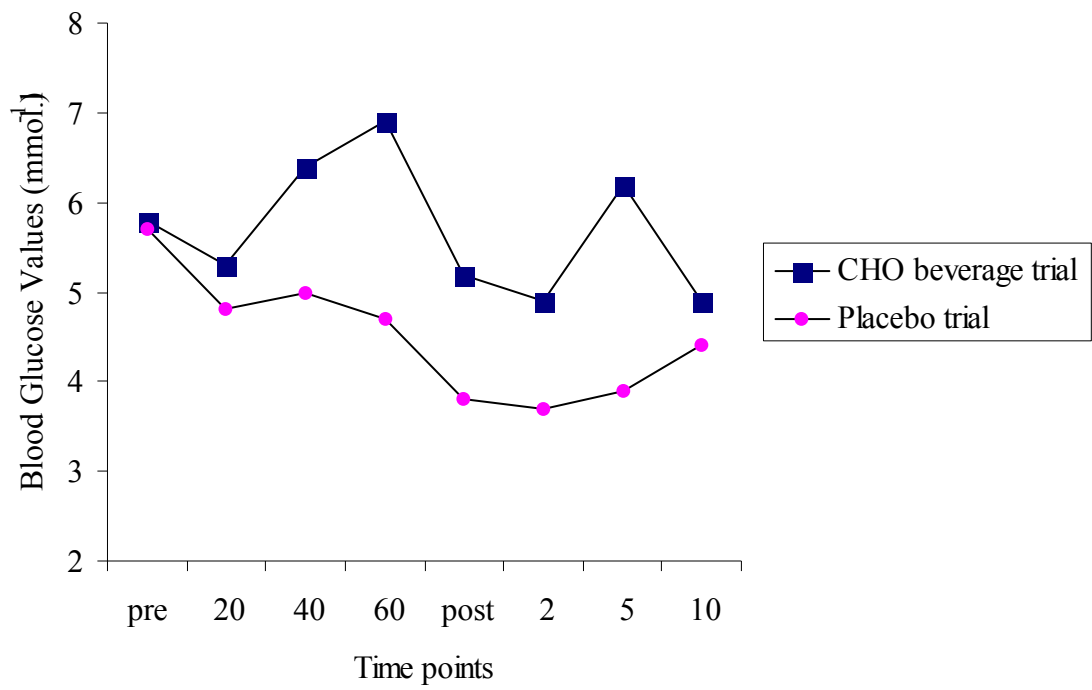
Distance Results:

Trial #	Drink #	60-min Distance (km)	Average Speed ( $\text{km}\cdot\text{h}^{-1}$ )	Max Speed ( $\text{km}\cdot\text{h}^{-1}$ )	P-Distance (km)	P-Avs ( $\text{km}\cdot\text{h}^{-1}$ )	P-Mxs ( $\text{km}\cdot\text{h}^{-1}$ )
1	Placebo	6.50	6.5	11.4	4.29	8.4	13.0
2	CHO	6.58	6.5	10.8	4.27	8.4	10.9

30-min Performance trial (P), Average Speed (Avs), Maximal speed (Mxs)

Participant comment at completion of exercise trial #1 with the placebo beverage was an overall body fatigue.





Participant 8: Female, 34 yrs, SCI T12-L1, 88.6 Kg, 185.4 cm

Distance Results:

Trial #	Drink #	60-min Distance (km)	Average Speed ( $\text{km}\cdot\text{h}^{-1}$ )	Max Speed ( $\text{km}\cdot\text{h}^{-1}$ )	P-Distance (km)	P-Avs ( $\text{km}\cdot\text{h}^{-1}$ )	P-Mxs ( $\text{km}\cdot\text{h}^{-1}$ )
1	CHO	7.21	7.2	8.9	3.80	7.6	8.8
2	Placebo	7.12	7.2	8.7	3.83	7.6	9.6

30-min Performance trial (P), Average Speed (Avs), Maximal speed (Mxs)

